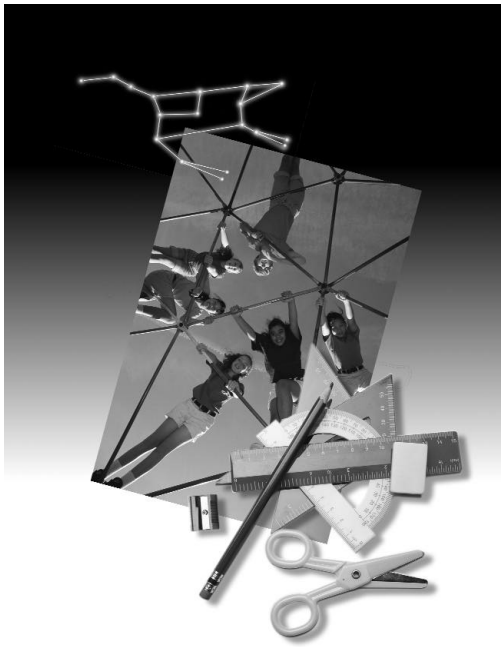
National Aeronautics and
Space Administration

Implementing the Office of Space Science (OSS) Education/Public Outreach Strategy



A Report by the
OSS-Space Science Advisory Committee
Education/Public Outreach Task Force

October 15, 1996

Dear Colleague:

We are pleased to release "Implementing the Office of Space Science (OSS) Education/Public Outreach Strategy"—a report prepared by the OSS-Space Science Advisory Committee Education/Public Outreach Task Force. We believe that the recommendations contained in this report will provide a solid basis for realizing the goals of the previously released "Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs" over the next several years.

The OSS Education/Public Outreach Strategy and the new implementation plan are a joint effort of our three Offices. They are one component of NASA's overall commitment to education and improving the public understanding of science. They are aimed at fulfilling the mandates in the NASA Strategic Plan to: "involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds" and "communicate widely the content, relevancy, and excitement of NASA's missions and discoveries to inspire and to increase understanding and the broad application of science and technology." They are aimed at expanding the impact of NASA's education/outreach programs by encouraging and facilitating the development of partnerships between the space science and education communities and by providing meaningful opportunities for underserved and underutilized groups.

We will continue to collaborate in the next phases of the implementation of OSS's approach to making education at all levels and the enhancement of the public understanding of science integral parts of space science missions and research activities. We believe that the innovative approach outlined in this implementation plan offers the prospect of enormous amplification of NASA's education/public outreach efforts. We look forward to working with you to use this implementation plan to turn OSS's Education/Public Outreach Strategy into a reality.

Sincerely,

WESLEY T. HUNTRESS, JR.
Associate Administrator for Space Science

GEORGE E. REESE
Acting Associate Administrator for Equal Opportunity Programs

SPENCE M. ARMSTRONG
Associate Administrator for Human Resources and Education

Table of Contents

Executive Summary 1

I. Introduction/Background 7

II. Creating an "Ecosystem" for Space Science Education and Outreach 9

III. Implementation Principles (Summary) 13

IV. Involve Scientists in Education and Outreach in Ways that Enhance Core OSS Research Goals 15

V. Make a Long-Term Sustained Commitment to Integrating Education and Outreach into OSS Missions and Research Programs 17

A. Validate Education and Outreach as a Priority for OSS 17
B. Provide Resources. 17
C. Build Education and Outreach into all Aspects of the OSS Program 17
D. Align Implementation Along OSS Themes 19
E. Recognize and Reward Contributions to Education and Outreach 20
F. Integrate Science and Education at the NASA Centers 21

VI. Support Local, State, and National Efforts Directed Towards Systemic Reform of Science, Mathematics, and Technology Education 23

VII. Base OSS-Developed Educational Products and Activities on the Criteria Contained in the National Mathematics, Science, and Technology Education Standards 25

VIII. Help Scientists Become Involved in Education/Outreach 27

A. Create a Network of Brokers/Facilitators 27
B. Provide Opportunities for Appropriate Training 28
C. Remove Contractual and Other Impediments to Participation 29

IX. Provide Meaningful Opportunities for Underserved and Underutilized Groups 31

X. Enhance the Breadth and Effectiveness of Partnerships Among Scientists, Educators, Contractors, and Professional Organizations as the Basis for OSS Education and Outreach Activities 33

A. Focus on High Leverage Opportunities 33
B. Build on Existing Programs, Institutions, and Infrastructure 34
C. Emphasize Collaborations with Planetariums and Science Museums 36
D. Coordinate With Other Ongoing Education and Outreach Efforts 36
i) Inside NASA 36
ii) Within Other Government Agencies 37
E. Involve the Contractors in OSS's Education/Outreach Programs 38

XI. Make Materials Widely Available and Easily Accessible, Using Modern Information and Communications Technologies Where Appropriate 41

XII. Evaluate for Quality, Impact, and Effectiveness 43

XIII. Funding 45

XIV. Next Steps 47

XV. Issues Requiring Attention 49

XVI. Concluding Remarks 51

Appendix A: Task Force Charter 53
Appendix B: Task Force Membership 55
Appendix C: Schedule of Task Force Activities 59
Appendix D: General References 61

Executive Summary

This Report summarizes the results of the deliberations of a Task Force of scientists and educators chartered by the Office of Space Science (OSS) and the Space Science Advisory Committee (SScAC) to consider how OSS's Education/Public Outreach Strategy—"Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs"— should be implemented.

The Report is organized around a broad systems approach (an "Ecosystem" for Space Science Education/Outreach) and a set of Implementation Principles which address both the operation of the "Ecosystem" and the specific actions recommended by the Task Force to realize the goals of the original Education/Outreach Strategy. *It should be read in conjunction with that Strategy which provides the policy guidance, rationale, and overall approach for OSS's involvement in education and the public understanding of science and describes the relationship of OSS's activities to NASA's overall education program.*

Creating an "Ecosystem" for Space Science Education/Outreach:

The Task Force has concluded that, in order to have a significant impact on improving the quality of science, mathematics, and technology education and the public understanding of science in the United States, OSS must take a comprehensive, integrated approach (described in Section II) to implementing its education and public outreach programs. Such a comprehensive approach—focusing on high-leverage activities and the creation of partnerships between the space science and education communities—is required to amplify the efforts of individual scientists and to ensure that limited funds and in-kind resources are channeled towards activities having the potential for state, regional, or national impact.

Considering formal education alone, the need for this type of approach emerges from a simple comparison of the size of the space science community in the United States (approximately 10,000 people) and the scale of the nation's education system:

- Number of Students: 48.9 million
- Number of Teachers: 2.9 million
- Number of Classrooms: 1.9 million
- Number of Schools: 110,000
- Number of School Districts: 15,200

The OSS budget proposed for FY 1997 is $1.86 billion. A few (1 to 2) percent of the OSS budget (which the Task Force suggests is an appropriate level for the total OSS investment in education/outreach—see below) is a few 10's of millions of dollars. The total expenditure on education at all levels across the United States by private organizations, local and state governments, and the federal government is more than $250 billion per year.

The conclusion arising from even a casual consideration of these numbers is inevitable. A series of one-on-one, or few-on-one interactions cannot have a significant impact on education and the public understanding of science at the national level. Every OSS-sponsored scientist would have to reach 5000 students each year and would have less than $1 per student per year to spend on materials, preparation,

and travel. It is clear that a different approach is required.

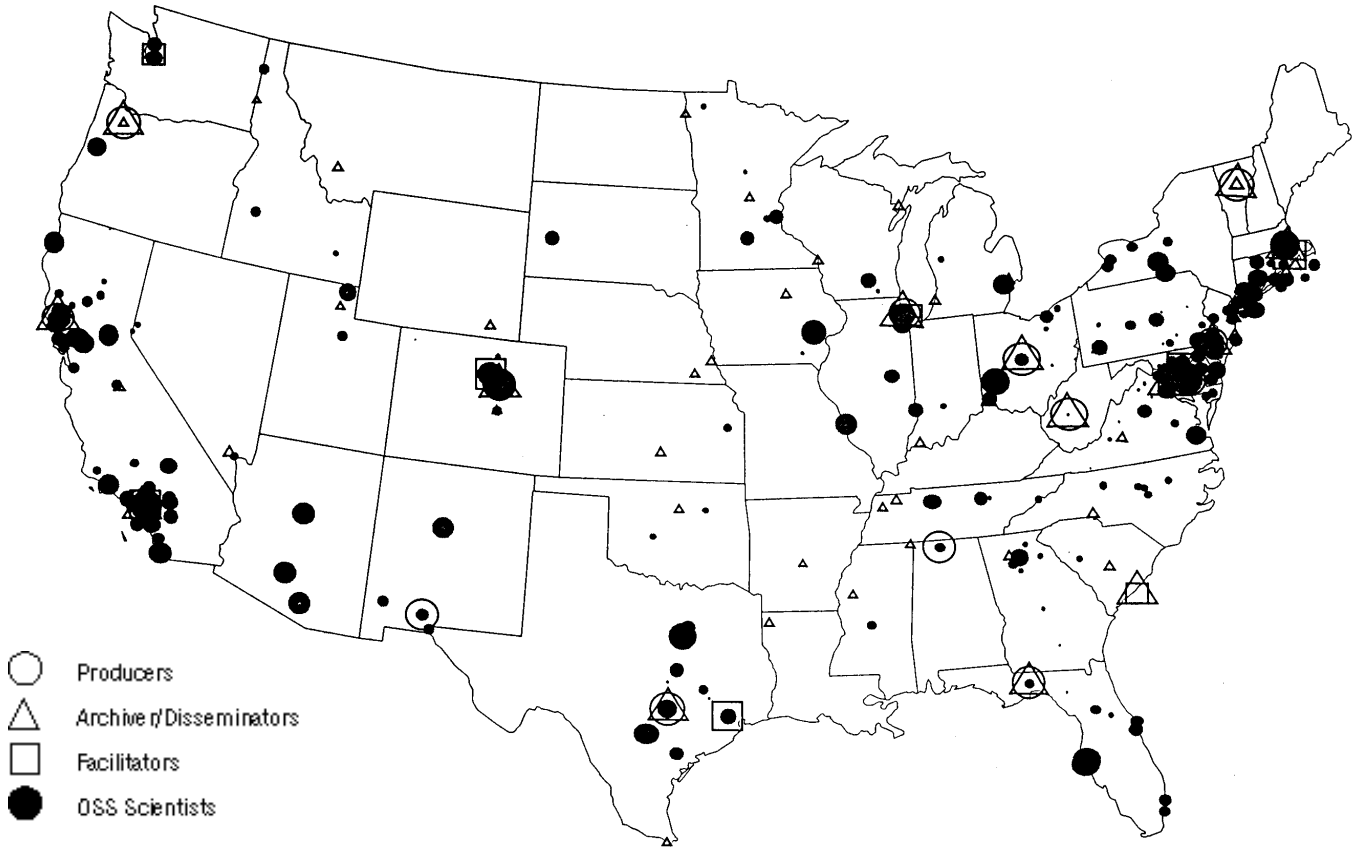
The basic approach proposed by the Task Force is to create a distributed, decentralized "Ecosystem" or network for space science education to foster a wide variety of highly-leveraged education/outreach activities. The results of those activities would then be disseminated across the country. The overall concept is illustrated schematically in Figure S-1 which shows a static view of the system. The distribution of symbols is intended to illustrate the concept and not to imply the selection of particular locations or institutions.

The foundation of this "Ecosystem" is the set of participants in the space science program located at universities, federal- and non-federal laboratories, and aerospace industries. Superimposed upon this foundation are sets of "nodes" of three different types:

- The producers of educational materials and products which draw upon the results of OSS activities. These products are in a form either directly usable or easily adaptable for use in education and public outreach;
- The archivers/disseminators of educational products who ensure that such products are known, widely available, and easily accessible;
- A set of brokers/facilitators who aggressively search out high leverage opportunities for educa-

Figure S-1

An "Ecosystem" for Space Science Education



A network for space science education to foster a wide variety of highly leveraged education and outreach activities. The results of those activities would be disseminated across the country.

tion/outreach; arrange alliances between individual scientists or scientific teams and educators to realize those opportunities; and, help the space science community turn results from missions and research programs into educationally appropriate products which can be distributed nationally.

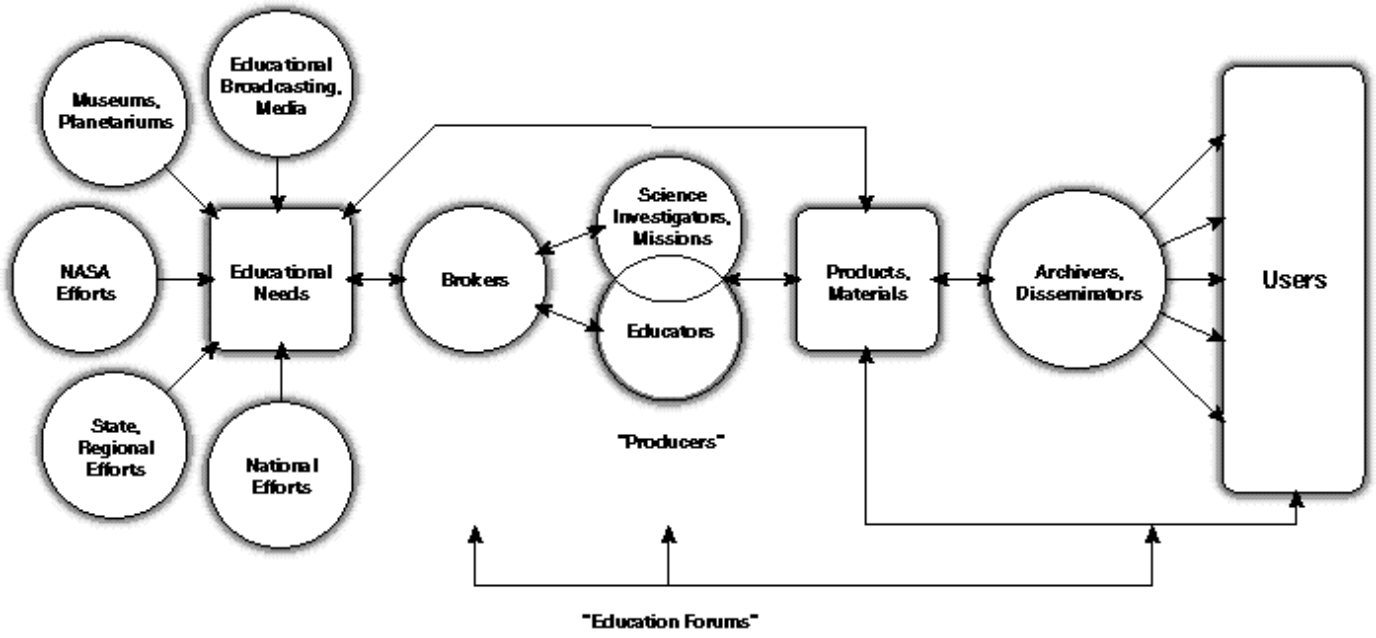
In many cases, existing institutions are in a position to take on one or more of these roles so that limited OSS resources can be directed towards value-added activities rather than the creation and maintenance of institutions. These different types of nodes are not necessarily located at the same institutions, although, in some cases, the Task Force finds there will be an advantage in aggregating functions to achieve a critical mass of activity in four major centers for space science education ("Education Forums") aligned with the four principal scientific themes contained in the OSS Strategic Plan.

How would such a system operate in practice? The basic flow is shown in Figure S-2 which starts with the identification of an educational need; continues with the formation of a partnership between scientists and educators (through the use of a broker/facilitator if necessary) for the specific purpose of meeting that need; and leads to the development of educational materials which are then catalogued and distributed by an archiver/disseminator to a wide variety of users. Section II contains additional discussion of the "systems" approach.

The operations of the "Ecosystem" are governed by a set of Implementation Principles which, *collectively*, define how OSS should proceed to implement its Education/Public Outreach Strategy. These Implementation Principles also can serve as a basis for making decisions concerning the types of education/outreach activities which OSS should sponsor and/or support.

Figure S-2

OSS Education "Ecosystem": Process and Interactions



The process starts with the identification of an educational need; continues with the formation of a partnership between scientists and educators; and leads to the development of education materials which are then catalogued and distributed by an archiver/disseminator to a wide variety of users.

Implementation Principles:

In implementing its education and public outreach strategy, OSS management and the OSS research community must:

- Involve scientists in education and outreach in ways that enhance core OSS research goals;

- Make a long-term sustained commitment to integrating education and outreach into OSS missions and research programs by:
  - Validating education/outreach as a priority for OSS,
  - Providing resources,
  - Building education and outreach into all aspects of the OSS program,
  - Aligning implementation along OSS themes,
  - Recognizing and rewarding contributions to education and outreach, and
  - Integrating science and education at the NASA Centers;

- Support local, state, and national efforts directed towards systemic reform of science, mathematics, and technology education;

- Base OSS-developed educational products and activities on the criteria contained in the national Mathematics, Science, and Technology Education Standards;

- Help scientists become involved in education/outreach by:
  - Creating a network of brokers/facilitators,
  - Providing opportunities for appropriate training, and
  - Removing contractual and other impediments to participation;

- Provide meaningful opportunities for underserved and underutilized groups;

- Enhance the breadth and effectiveness of partnerships among scientists, educators, contractors, and professional organizations as the basis for OSS education and outreach activities by:
  - Focusing on high leverage opportunities,
  - Building on existing programs, institutions, and infrastructure,
  - Emphasizing collaborations with planetariums and science museums,
  - Coordinating with other ongoing education and outreach efforts:
    - Inside NASA,
    - Within other government agencies,
  - Involving the contractors in OSS's education/outreach programs;

- Make materials widely available and easily accessible, using modern information and communication technologies where appropriate; and

- Evaluate for quality, impact, and effectiveness.

The Implementation Principles are individually discussed in Sections IV through XII of this Report. Each section describes the background and logic used in arriving at that Principle, what that Principle means in practice, and how it contributes to the overall operation of the "Ecosystem". Each section contains a set of Findings and Recommendations which are the specific actions which the Task Force has concluded are required to implement that Principle; develop the critical components of the "Ecosystem"; embed education and public outreach into all aspects of the OSS program; establish the wide range of alliances (both inside and outside of NASA) needed to make the most effective use of limited OSS resources; and provide a variety of opportunities for the space science community to become more effectively engaged in pre-college education and the public understanding of science.

Near-Term Actions:

The Task Force has identified a subset of the total of more than 50 individual Findings and Recommendations presented throughout the Report which require near-term actions by OSS management in order to proceed with the development of the "Ecosystem" for space science education and public outreach.

- OSS must make a commitment to provide adequate funds for education and outreach, identify the source of funds, and allocate those funds appropriately. (See Sections V-B,-C,-D, and XIII.)

As a long-term goal, the Task Force recommends that OSS should plan to spend 1 to 2 percent of its total budget on education and the public understanding of science.

As discussed in Sections V, XIII, and XIV, such funding would be used to foster a wide variety of activities and put key elements of the "Ecosystem" into place. In particular, support would be provided for:

- The education/outreach components of individual research projects;
- An OSS-wide program of small education grants;
- A small number of carefully selected major education programs and projects chosen on the basis of their prospects for having significant regional or national impact;
- A small (four to six in total) set of regional brokers/facilitators;
- The education/outreach components of individual flight missions;
- The four theme-oriented "Education Forums."

The Task Force expects that the predominant fraction of the available funding would be used to support individual or mission-oriented education/outreach programs and projects directly involving the OSS research community. As discussed in Sections XII and XIV, decisions regarding continuing long-term support of groups and institutions (in particular, the "Education Forums" and the broker/facilitators) should be based on periodic evaluations of performance.

- Education, outreach, and the provision of opportunities for underserved/underutilized groups must begin to appear as specific goals (with appropriate evaluation criteria) in all OSS Announcements of Opportunity and NASA Research Announcements. These aspects of proposals should be reviewed with the same professional care and expertise as is now done for the scientific aspects of proposals. (See Sections V-C and IX.)

- OSS should begin discussions with candidate organizations regarding their assuming the role of "Education Forums" and to more precisely define the scale and scope of the activities to be undertaken by these centers for space science education. While it appears that there are reasonable choices for institutions to assume the role of "Education Forum" for the four OSS scientific themes, the pros and cons of carrying out an open competition for the selection of these institutions should be carefully explored. (See Section V-D.)

- OSS should initiate action to select and fund the first set of brokers/facilitators. Initial selections should be made competitively for a 2- to 3-year period with careful attention paid to assessment of performance throughout that period. Several types of groups/institutions should be selected to allow a thorough exploration of a variety of approaches to carrying out this function. At least one of the broker/facilitators selected should involve a minority institution or (preferably) a consortium of minority institutions/organizations specifically charged with identifying opportunities and establishing alliances between minority institutions and the space science research community. (See Sections II, VIII-A, IX, and XV.)

- OSS should initiate discussions with a variety of institutions and organizations outside NASA to explore the role such groups might play in the implementation of the OSS Education/Outreach Strategy. Examples of such groups include the National Science Foundation, the Association of Science and Technology Centers, the International Planetarium Association, the National Science Teachers Association, professional organizations such as the American Astronomical Society and the American Geophysical Union, and OSS's contractors. (See Sections X-B,-C,-D, and -E.)

- An OSS Education/Outreach Management Operations Working Group (or perhaps an Advisory Subcommittee to SScAC itself) should be set up to oversee progress with the implementation of the Education/Outreach Strategy, review

accomplishments, and recommend changes in the implementation plan which may be required on the basis of performance and experience. (See Section XII.)

Three issues have been identified (see Section XV) as needing further attention from OSS management, follow-on study groups, or the Space Science Advisory Committee itself. These are:

- Assessment and evaluation. A follow-on study is needed to develop an integrated approach to the evaluation of the total OSS Education/Outreach program.

- Minority/underserved institutions. OSS and the space science community do not have an adequate understanding of the skills, capabilities, and needs of such institutions and their students. Steps (including visits and widespread consultation) must be taken to achieve such an understanding. Attention must also be paid to finding effective mechanisms to involve such institutions in the space science program and create real opportunities for participation.

- Support of graduate students. OSS's basic policies should be re-examined. This re-examination should consider such issues as the nature of future professional opportunities and whether OSS should consider supporting students interested in science education. It should build upon existing and ongoing work and focus on the unique circumstances and needs of students in the space science community.

The Task Force concludes that, by forming appropriate partnerships with the education community, by consciously and deliberately seeking the highest leverage opportunities through such partnerships, by taking maximum advantage of existing programs and institutions, and by adopting an integrated systems approach to the implementation of its education/outreach program, OSS and the OSS research community can make a significant and lasting contribution to improving education and raising the public understanding of science.

The systems approach outlined in this Report should serve to channel the efforts of the space science research community in the most productive directions while still encouraging individual initiative and creativity. It should promote the best use of the time and talents of OSS-supported scientists and the unique results being obtained from OSS research programs and spaceflight missions. It should help foster a wide range of alliances between the research and education communities and, in so doing, contribute to the solution of significant national problems.

The overall approach described in this Report is an experiment. The focus on process as the centerpiece of this experiment, rather than on the identification of a set of specific programs, represents a deliberate choice by the Task Force to depart from the practice of simply creating a collection of stand-alone activities having purely local impact. The proposed process offers the prospect of enormous amplification of OSS's education/outreach efforts. The only way to tell whether the experiment will work is to try it. Flexibility will be required, progress on the experiment will have to be monitored closely, and adjustments made on an ongoing basis.

Realism about expectations is important. No single education or outreach program undertaken or sponsored by OSS will, by itself, have a significant, long-term, sustainable impact on the American educational system. Rather, it will be the total effect of a broad ensemble of high-leverage activities carried out over a long period of time which can make a difference. A long-term commitment is crucial for success.

I
Introduction / Background

Scientists and educators coming together to share new discoveries, the process of doing science and its joys and creativity; and to develop effective strategies for making both the results and the process of science available to all students and the public.

This Report summarizes the results of the deliberations of a Task Force of scientists and educators chartered by the Office of Space Science (OSS) and the Space Science Advisory Committee (SScAC) to consider how OSS's Education/Public Outreach Strategy should be implemented.

The Report is organized around a broad systems approach (an "Ecosystem" for Space Science Education/Outreach described in Section II) and a set of Implementation Principles (summarized in Section III) which, *collectively*, define the operation of the "Ecosystem" and address the specific actions recommended by the Task Force to realize the goals of the original Education Strategy. *Sections IV-XII discuss in some detail the major findings and recommendations associated with each Implementation Principle.* Subsequent sections deal with funding, the next steps required to proceed with the implementation of the Strategy, and a discussion of issues requiring further attention. *This Report should be read in conjunction with the OSS Education/Public Outreach Strategy which provides the policy guidance, rationale, and overall approach for OSS's involvement in education and the public understanding of science.*

"Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs" was released by OSS in March 1995. This Strategy—which is one component of NASA's overall contribution to a national initiative to dramatically improve science, mathematics, and technology understanding in the United States—was developed in collaboration with NASA's Offices of Human Resources and Education and Equal Opportunity Programs. It described OSS's approach for making education at all levels and the enhancement of the public understanding of science integral parts of space science missions and research activities. It announced new policies regarding the infusion of education and public outreach into all OSS missions and programs. It focused on the need for forming long-term partnerships between the space science and education communities as the key to the effective implementation of the Strategy.

At the time of its release, it was generally recognized that the Education/Public Outreach Strategy was essentially a policy document. It laid out a set of long-term goals and painted a very broad-brush picture of the basic approaches to be taken to realize those goals. It was also obvious that there were a substantial number of important practical questions that needed to be addressed in detail in order to proceed with the most effective implementation of the Strategy.

In order to address these questions, a Task Force was set up under the NASA Advisory Council's Space Science Advisory Committee in July 1995. The Task Force's charge (see Appendix A) was to frame the issues which must be addressed in the implementation of the OSS Education/Public Outreach Strategy; seek opinions, ideas, and suggestions from the various concerned communities as to how the Strategy should be implemented and what specific policies and practices should be adopted; examine possible alternative approaches to the implementation of the Strategy; and develop a set of implementation approaches for consideration by the Space Science Advisory Committee and the Associate Administrator for Space Science.

Members of the Task Force (see Appendix B) were selected to provide a wide variety of perspectives concerning the implementation of the OSS Education/Public Outreach Strategy. Participants included representatives from the space science community, the formal and informal education communities, individuals involved in mathematics and science systemic reform, practicing teachers at several levels in the education system, NASA Headquarters, NASA Centers and research institutes, minority universities and colleges, and industry.

The Task Force held a total of four meetings between September 1995 and April 1996 (see Appendix C for a detailed schedule of activities). In December 1995, a Survey was distributed to obtain information and solicit the views of a broad segment of the research community on a number of critical issues relating to the implementation of the OSS Education/Public Outreach Strategy. An associated questionnaire was posted on the World Wide Web. Responses to the Survey were reviewed and considered by the full Task Force. During the course of the study, a number of *ad hoc* subgroups drawn from Task Force membership were established to examine specific issues of in some depth. A 2-day Workshop was held in Charleston, South Carolina in March 1996 to examine the role that the Space Grant Colleges and Universities might play in the implementation of the OSS Strategy. Individual assignments were also made. Results of all of these activities were considered by the full Task Force in arriving at its findings and recommendations.

II
Creating an "Ecosystem" for Space Science Education and Outreach

FINDING: The Task Force finds that, in order to have a significant impact on improving the quality of science, mathematics, and technology education and the public understanding of science in the United States, OSS must take an integrated approach to implementing its education/outreach program. Such an approach can substantially multiply the efforts of individual scientists. Without such leverage, the impact of OSS efforts will be very limited.

The rationale behind this statement is straightforward. Figure 2-1 shows the distribution of OSS Principal Investigators (both for missions and research programs) across the United States in FY 1994. Adding in reasonable allowances for the number of Co-Investigators, Research Associates, and Graduate Students associated with research teams, a reasonable upper limit to the number of space scientists across the country is approximately 10,000.

This number then must be compared with the scale of the education system in the United States (numbers for 1993 from the National Center for Education Statistics):

- Number of Students: 48.9 million
- Number of Teachers: 2.9 million
- Number of Classrooms: 1.9 million
- Number of Schools: 110,000
- Number of School Districts: 15,200

A few other numbers are relevant. The OSS budget proposed for FY 1997 is $ 1.86 billion. A few (1 to 2) percent of the OSS budget (which the Task Force finds is an appropriate level for the total OSS investment in education/outreach) is a few 10's of millions of dollars. The total expenditure on education at all levels across the United States by private organizations, local and state governments, and the federal government is more than $250 billion per year.

The conclusion arising from even a casual consideration of these numbers is inevitable. *A series of one-on-one, or few-on-one interactions cannot have a significant impact on education and the public understanding of science at the national level.* Every OSS-sponsored scientist would have to reach 5000 students each year and would have less than $1 per student per year to spend on materials, preparation, and travel.

The Task Force concludes that the solution to this problem is to de-emphasize few-on-one interactions and take a systems-oriented, high leverage approach to the implementation of the OSS Education/Public Outreach Strategy.

The basic approach proposed by the Task Force is to create a distributed, decentralized "Ecosystem" or network for space science education within which a wide variety of highly-leveraged education/outreach activities can be fostered and undertaken. The results of those activities can then be disseminated widely across the country using a variety of mechanisms. The overall concept is shown in Figures 2-2 and 2-3.

The distribution of individuals and institutions within such an "Ecosystem" is illustrated schematically in Figure 2-2. The purpose of Figure 2-2 (which provides a static view of the system—the dynamics are described below) is to illustrate the concept and not to imply the selection of particular locations or institutions.

The foundation of this "Ecosystem" is the set of participants in the space science program located at universities, federal- and non-federal laboratories, and aerospace industries across the country. Superimposed upon this

foundation are sets of three different types of "nodes" whose functions are outlined below and described in more detail in Sections V, VIII, and XI. These different types of nodes are not necessarily located at the same institutions, although the Task force finds there will be an advantage in aggregating functions to achieve a critical mass of activity in four major centers for space science education ("Education Forums"—see Section V-D) aligned with the four principal scientific themes contained on the OSS Strategic Plan. In many cases, existing institutions are in a position to take on one or more of these roles so that limited OSS funds can be directed towards value-added activities rather than the initial creation and subsequent maintenance of institutions.

The first type of node is dedicated to the *production* of educational materials and products which draw upon the results of OSS activities. These products are in a form either directly usable or easily adaptable for purposes of education/public outreach. The Hubble Space Telescope Science Institute is one example of an institution which has already taken on this role for space astronomy.

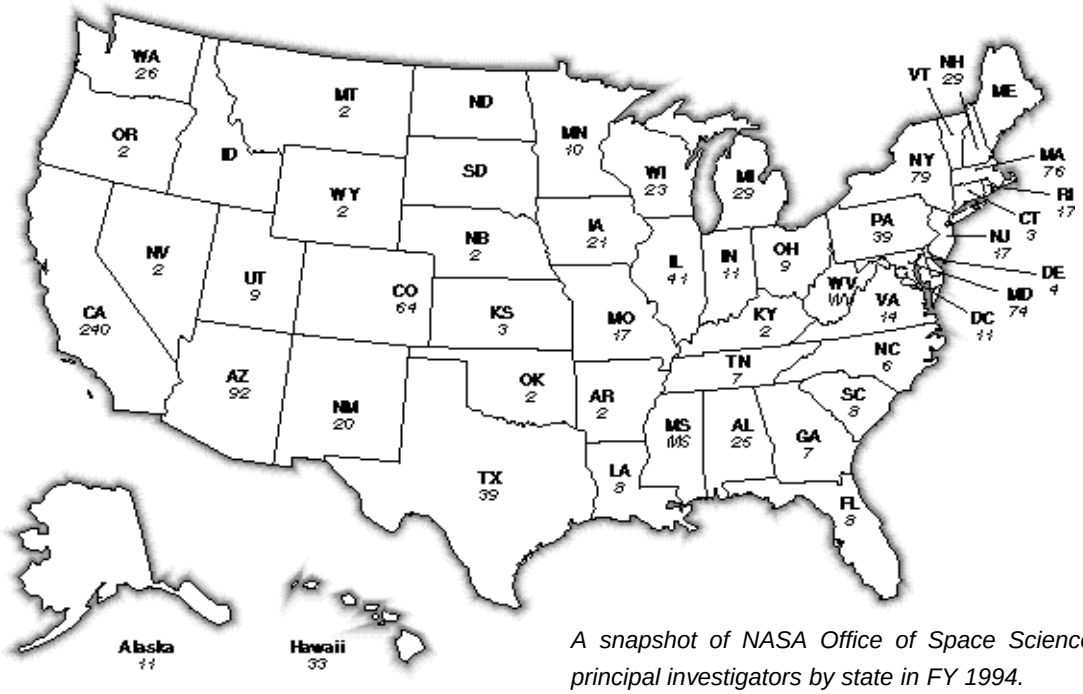
The second type of node is dedicated to the *archiving and dissemination* of education/outreach products so that such products are widely available and easily accessible. The existing national network of NASA Teacher Resource Centers could serve this purpose as could a variety of other existing public and private institutions and organizations (such as the Eisenhower Regional Centers) whose purpose is to distribute science, mathematics, and technology curriculum materials (see Sections X-B and XI).

The third set of nodes distributed across the country are the *brokers/facilitators* whose functions are described in more detail in Section VIII-A. The Task Force believes that this role—which is a new function—is central to the successful operation of the entire network. The principal functions of these brokers/facilitators are to aggressively search out the highest leverage opportunities for education/outreach across the country; arrange alliances between educators and individual scientists or scientific teams to realize those opportunities; and help participating scientists turn results from space science missions and research programs

Figure 2-1

OSS Principal Investigators by State

Total PIs = 1,145 (FY 1994)



A snapshot of NASA Office of Space Science principal investigators by state in FY 1994.

into educationally appropriate products which can be distributed nationally. While the broker/ facilitator concept is clearly a new one for OSS, existing institutions such as the Space Grant colleges and universities could take on this role.

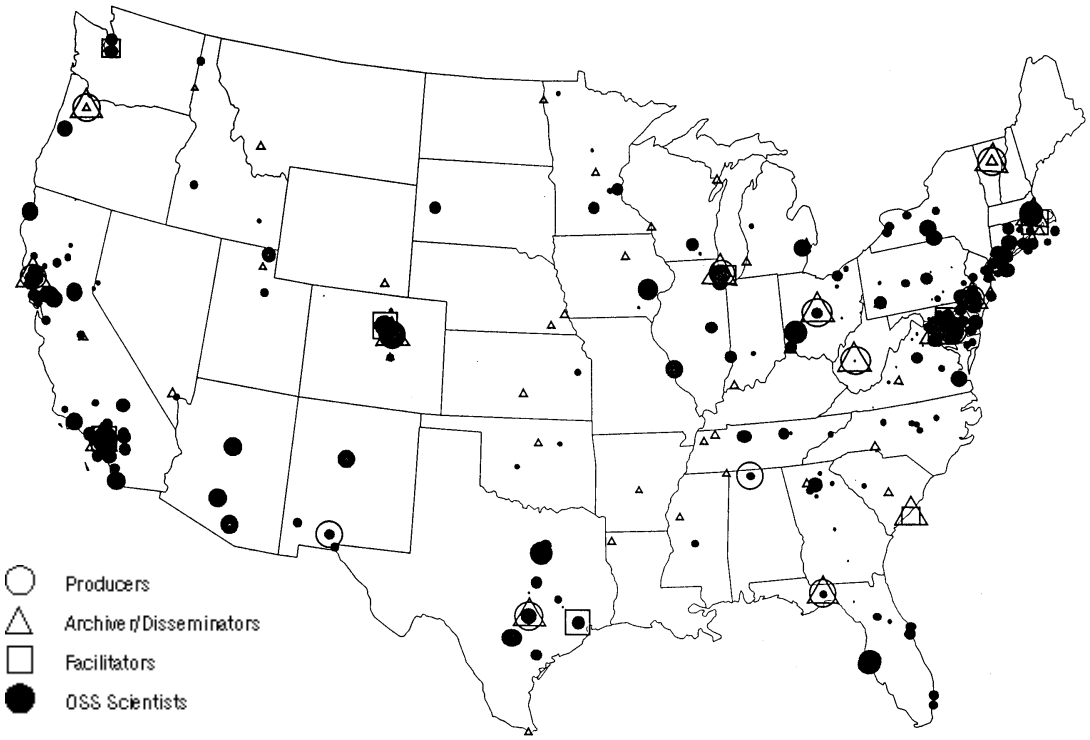
How would such a system operate? The basic flow is shown in Figure 2-3 which starts with the identification of an educational need; continues with the formation of a partnership between scientists and educators (through the use of a broker/facilitator if necessary) for the specific purpose of meeting that need; and leads to the development of educational materials which are then catalogued and distributed by an archiver/disseminator to a wide variety of users.

As a specific example of how this process would work, suppose a planetary astronomer in Arizona has observed Jupiter's and Saturn's atmospheres with the Hubble Space Telescope and would like to develop resource materials that could be used to supplement existing curriculum units dealing with Earth's wind and weather. The astronomer could contact either a broker/facilitator or an "Education Forum" to request a listing of educators (or educational organizations) involved in the development and dissemination of such curriculum units. Aided by this information, the astronomer could then contact these educators/organizations, assess their needs, and work with them to generate appropriately tested resource materials that could be directly incorporated by the educators into their curriculum units. Such resource materials would also be catalogued and disseminated by archivers/disseminators or "Education Forums" to assure maximum utilization of the resource materials both by other educators and the space science community.

As a second example, an education group working on curriculum development at the state level in

Figure 2-2

An "Ecosystem" for Space Science Education



A network for space science education to foster a wide variety of highly leveraged education and out - reach activities. The results of those activities would be disseminated across the country.

Wyoming identifies a need for some scientific help. This group could turn to a regional facilitator in Colorado who, in turn, finds an individual investigator in Utah who is interested in spending a modest amount of time on such an activity. The broker/facilitator would work with both parties to create the partnership. The partners could turn to one or more of the product creators for existing materials which could be used or adapted to meet the needs of the particular curriculum project. When the resulting curriculum units are finally developed and tested (using the expertise of the educator half of the partnership), arrangements would be made (through either an archiver or a broker/facilitator) for the cataloguing and distribution of materials through a national network.

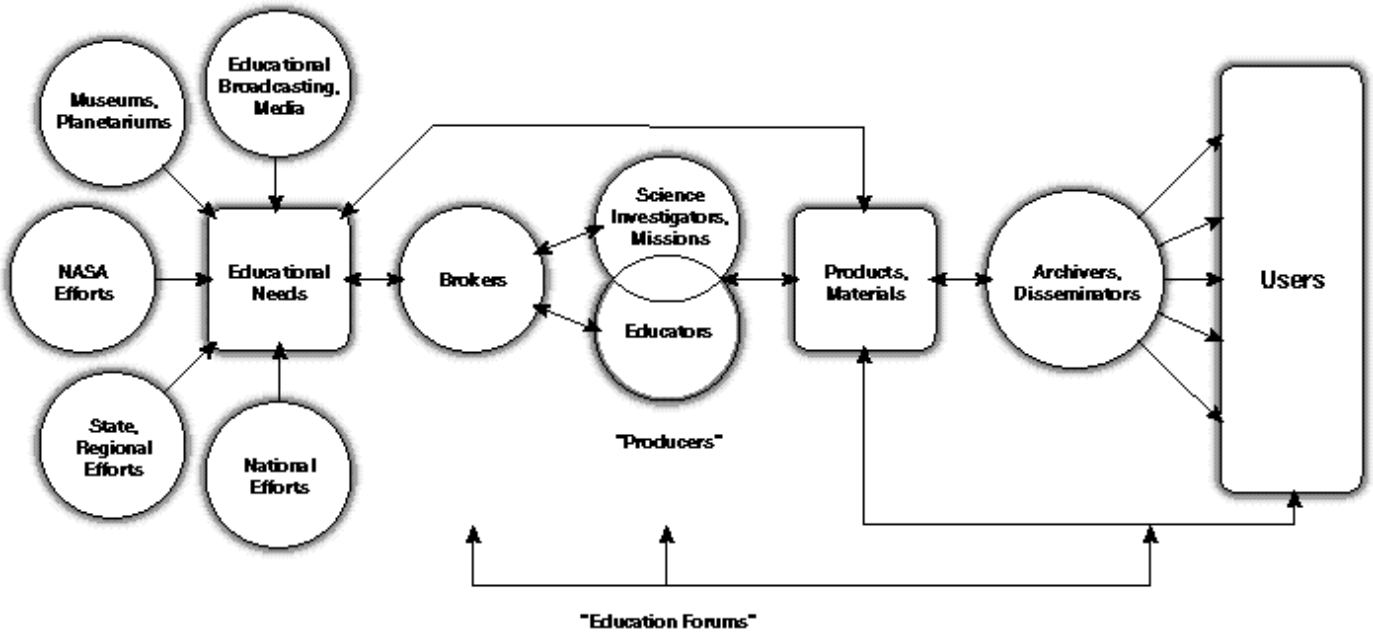
Similarly, scientific teams interested in developing an education/outreach program in response to an Announcement of Opportunity could receive help from a broker/facilitator to identify suitable opportunities and alliances.

Availability of the various types of nodes in the network is intended to help participating scientists maximize the return from a limited investment of time and resources in education and public outreach. It is intended to provide help to individual scientists or scientific teams in finding high leverage activities, creating alliances with appropriate partners, and channeling the results from education/outreach programs into national dissemination networks.

If such help is not needed by a particular group, there is no requirement to use the machinery. The only requirement is general adherence to the overall set of Implementation Principles which are intended to define and guide the operation of the "Ecosystem" as a whole.

Figure 2-3

OSS Education "Ecosystem": Process and Interactions



The process starts with the identification of an educational need, continues with the formation of a partnership between scientists and educators, and leads to the development of education materials which are then catalogued and distributed by an archiver/ disseminator to a wide variety of users.

III
Implementation Principles (Summary)

FINDING: In implementing its education and public outreach strategy, OSS management and the OSS research community must:

- Involve scientists in education and outreach in ways that enhance core OSS research goals;

- Make a long-term sustained commitment to integrating education and outreach into OSS missions and research programs by:
  - Validating education/outreach as a priority for OSS,
  - Providing resources,
  - Building education and outreach into all aspects of the OSS program,
  - Aligning implementation along OSS themes,
  - Recognizing and rewarding contributions to education and outreach,
  - Integrating science and education at the NASA Centers;

- Support local, state, and national efforts directed towards systemic reform of science, mathematics, and technology education;

- Base OSS-developed educational products and activities on the criteria contained in the national Mathematics, Science, and Technology Education Standards;

- Help scientists become involved in education/outreach by:
  - Creating a network of brokers/facilitators,
  - Providing opportunities for appropriate training,
  - Removing contractual and other impediments to participation;

- Provide meaningful opportunities for underserved and underutilized groups;

- Enhance the breadth and effectiveness of partnerships among scientists, educators, contractors, and professional organizations as the basis for OSS education and outreach activities by:
  - Focusing on high leverage opportunities,
  - Building on existing programs, institutions, and infrastructure,
  - Emphasizing collaborations with planetariums and science museums,
  - Coordinating with other ongoing education and outreach efforts:
    - Inside NASA,
    - Within other government agencies,
  - Involving the contractors in OSS's education/outreach programs.

- Make materials widely available and easily accessible, using modern information and communication technologies where appropriate;

- Evaluate for quality, impact, and effectiveness.

These principles have to be treated as an integrated set. They each illuminate a different aspect/characteristic of the overall "systems" approach to education and public outreach proposed by the Task Force. They *collectively* define the way that the Task Force concludes that OSS should proceed to implement its

Education/Public Outreach Strategy. The Implementation Principles can also serve as a basis for making decisions concerning the type of education/outreach activities which OSS should sponsor and/or support.

The next nine sections discuss each of the Implementation Principles in more detail and present a series of Findings and Recommendations as to how those principles are to be put into practice.

IV
Involve Scientists in Education and Outreach in Ways that Enhance Core OSS Research Goals

FINDING: Implementation of the OSS Education/ Outreach Strategy must involve the scientific participants in ways that: preserve OSS research goals; make a genuine contribution to education and the public understanding of science; permit scientists to continue to function as scientists; and make optimum use of their time and expertise. The integrated approach described in this Report is aimed towards achieving these goals.

The strength of the OSS research community and the unique contribution that it can make to education and public outreach is based on the fact that it is a source of continuing new knowledge and new discoveries that can inform teachers at all levels and excite students and the public about science. Space scientists:

- Are a living demonstration that science is a human endeavor carried out by real people of all kinds who have many different types of skills and who approach their science in many different ways;
- Possess an enthusiasm for science and a way of looking at the world to try to understand why things work the way they do;
- Have a presence in colleges and universities, research laboratories, and industry in communities across the country;
- Can communicate and provide information on the latest exciting research results.

Their contributions to education and outreach must draw on these attributes.

But to be most effective, the limited time and resources of the scientific community must be highly leveraged and properly channeled. Scientists can provide information and ideas. Educators can package the results in formats useful in the classroom and understandable to students and the public. Scientists must receive help in locating opportunities that make the best use of their time, talent, and interests. Educational activities that are developed and tested locally must be made available nationally. And materials must be tested for quality and effectiveness.

The remaining principles are devoted to considering various approaches to achieving these ends.

V

Make a Long-Term Sustained Commitment to Integrating Education and Outreach into OSS Missions and Research Programs

FINDING: Successfully integrating education and public outreach into OSS missions and research programs requires a long-term sustained commitment by NASA management, the entire OSS management team and all the participants in the space science program.

A number of specific steps must be taken both to demonstrate the sincerity of that commitment and to infuse education/outreach throughout every aspect of OSS's activities. The following six subsections outline the most important actions that the Task Force finds are needed to achieve that integration.

A. Validate Education/Outreach as a Priority for OSS

FINDING: Education and Outreach must be the collective responsibility of all of OSS's management and of all the participants in the OSS program.

Members of the OSS Board of Directors, OSS Division Directors, Science Discipline Managers, and Mission Program Scientists must assume responsibility for advocating, supporting, and rewarding contributions to education and public outreach within their areas of responsibility just as conscientiously as they do for all the other aspects of their programs. Science and mission managers at the NASA Centers including Program/Project Managers and Project Scientists must also assume such responsibility.

OSS must also provide guidelines and incentives to ensure that OSS-supported scientists are empowered to carry out education and outreach work. All parties must recognize and accept that contributing to education and the public understanding of science are legitimate functions of the work of the scientific, engineering, and management employees working on OSS-funded activities.

B. Provide Resources

FINDING: Funding is the sincerest form of flattery.

The approach presented in this Report will produce a large return for a very modest investment but a significant education/outreach program cannot be done for free. In a declining budget environment, the Task Force recognizes that the necessary resources can only be obtained by diverting them from other research and development activities. Such a diversion will have some impact on those other activities. Less research will be done. Mission costs will go up or there will be some reductions in mission scope in order to accommodate education/outreach activities within a fixed budget envelope. Nevertheless, *the Task Force has concluded that a modest (1-2 %) reallocation of funds is justified and appropriate so that OSS and the space science community can respond to national mandates for increased involvement in education and the public understanding of science*. Further discussion of funding requirements is presented in Section XIII.

C. Build Education and Outreach Into All Aspects of the OSS Program

FINDING: Every participant in the OSS science program—ranging from individual investigators sup-

ported by modest research grants to the science and engineering teams responsible for major flight programs taking many years to design, develop, and operate and involving hundreds of millions of dollars—has the potential for making a valuable contribution to education and the public understanding of science.

The overall goal of this Implementation Plan is to develop a variety of mechanisms to realize this potential, to encourage and help the OSS research community to become involved in education/outreach, and to embed education/outreach throughout the OSS program. A number of steps must be taken to achieve these ends.

RECOMMENDATION: Provisions for education/outreach should be built into research grants.

NASA Research Announcements (NRA's) should contain explicit education and public outreach goals and appropriate evaluation criteria. The education/outreach components of proposals should be evaluated by educators and treated as professionally as the scientific components of proposals. Funding should be made available to support education/outreach activities as an integral part of each research program.

The Task Force is *not* saying that education and outreach should be a required part of every research proposal and that every individual investigator must be involved in education/outreach. Rather, *making a contribution to education/outreach should be encouraged through the provision of funding and by attaching enough weight to education in the evaluation process that, in the case of closely competing proposals, the value of the contribution to education may actually influence selection.*

A variety of approaches are possible in practice. Individual proposers could be encouraged to spend a modest fraction of their total effort on education/outreach (with explicit allowance for such activities built into the budget), science and education aspects of proposals could be evaluated separately (with appropriate weights), and then the total evaluation used as the basis for selection. A decision could also be made to select a proposal purely on scientific grounds, and then a separate decision made to fund the education/outreach component of a proposal from a pool of funds set aside for this purpose. Whatever approach is taken, it is the principle that is crucial: *contributing to education/outreach is important, it counts, the means will be provided to build it in to research programs, and it is a legitimate activity to be carried out as an integral part of those research programs.*

RECOMMENDATION: Education and outreach should be built in to investigations and flight missions selected through the Announcement of Opportunity (AO) process. AO's should contain explicit mandatory education/outreach goals and evaluation criteria.

While the scientific aspects of such proposals must continue to be the primary basis for selection, enough weight should be given to education/outreach for it to be a meaningful factor in the selection process. Education/outreach components of proposals should be evaluated by appropriate professionals. In general, 1 to 2 percent of mission budgets should be devoted to education/outreach.

In the case of large missions, it may make sense to develop stand-alone education programs, although there should be strong coordination among missions so that the ensemble of activities undertaken across OSS missions can complement each other, assure consistency of quality, share lessons learned, and arrange for the evaluation and broad dissemination of materials. Project Offices should be responsible for the development of an Education/Outreach Plan with professional educators involved in the development and implementation of that plan.

For small and medium missions, more limited resources will be available for education/outreach. In this case, it makes less sense for every individual mission to develop its own infrastructure and separately arrange for carrying out such functions as evaluation and distribution of materials. The "Education Forums" described in Section V-D could carry out such functions for the smaller missions, enabling those missions to focus their education/ outreach resources on the unique aspects of those missions—unique aspects which can add value to a more comprehensive, theme-oriented education program.

RECOMMENDATION: To encourage involvement, experimentation, and the development of innovative approaches to education and outreach by the space science research community, OSS should create an expanded program of small grants.

Such a program could be modeled on the very successful Initiative to Develop Education through Astronomy (IDEA) program but generalized to cover all of the OSS research disciplines.

In view of the Hubble Space Telescope Science Institute's experience in administering the IDEA program, it seems both reasonable and natural to turn to the Institute to take on the responsibility for this expanded program. Having a single home for the entire program would foster more effective coordination of individual activities, the sharing of experience and results, and the broad dissemination of the most effective products emerging from individual grants.

RECOMMENDATION: OSS should provide funds to support a limited number of carefully selected, larger, more ambitious education/outreach efforts than can be done within the scope of the small grant program recommended above. Such activities should be regional or national in scope, have the potential for reaching large audiences, or have a major impact on the incorporation of space science into the educational process.

The Task Force recognizes that there are some important, high-visibility, high-impact education/outreach activities which will require significant funding. Possibilities include the development of major museum displays or planetarium shows and the production of educational television programs based on the results of space science programs. While it is clearly not feasible to support even a small fraction of the possibilities, OSS should have the means and the flexibility to support a few such activities each year. The Task Force also recognizes that, for major activities, OSS funding may not be the only or even the predominant source of support. OSS funding may be important for leveraging other funds or providing the seed money for developing other possible sources of support.

D. Align Implementation Along OSS Themes

RECOMMENDATION: OSS should establish four major centers for space science education ("Education Forums") aligned with the four principal scientific themes contained in the OSS Strategic Plan.

The Task Force has concluded that there are major advantages associated with adopting a theme-oriented approach to education and public outreach and establishing a small number of institutions where a critical mass of scientific and educational expertise exists to act as major nodes in the network described in Section II.

- Focusing on the four OSS Themes —Structure and Evolution of the Universe, Astronomical Search for Origins and Planetary Systems, Solar System Exploration and The Sun-Earth Connection—will facilitate the development of educational activities and products aligned to the needs of the educational system.

- Having centers of scientific/educational expertise associated with specific themes will provide a natural "home base" for the education/outreach programs of the smaller missions as well as a broader context for the educational contributions of individual missions. As discussed earlier, the "Education Forums" can provide a number of essential services for the smaller missions so that each mission does not need to create its own infrastructure.

- The "Education Forums" can provide the necessary sustained effort and long-term continuity required to effectively work with the educational system—a continuity which cannot be provided by short duration missions or activities undertaken as a part of individual research grants.

The Task Force envisions that the "Education Forums" will take on a broad range of responsibilities for education and outreach in their theme area including:

– Playing the role of national broker/facilitator for missions, data archives and research programs associated with particular themes;

– Working with the education community to develop educational programs and products suitable for national distribution;

– Ensuring that new scientific results are incorporated into educational programs and products in a timely manner;

– Serving as archiver and/or disseminator for education/outreach products and programs;

– Creating and maintaining an accessible directory of education/outreach products and materials that can be used by anyone requiring assistance in locating such resources.

In some cases, existing institutions are already well-positioned to take on this role. In other cases, while there are plausible candidate institutions (see below), the capability, interest, and willingness of such groups to take on this role is not as well-defined. *Additional work will be required to define the precise scope, range of activities, and resources required to support each of the "Education Forums". Such work can only be done through close consultation with the institutions which are reasonable candidates to take on these roles.*

Candidate institutions (identified by the Task Force on the basis of its understanding of the scientific/educational capabilities of a wide variety of institutions as well as their other broad responsibilities within the OSS program) for taking on the role of "Education Forum" for the four OSS themes include:

Theme	*Candidate Institution*
Structure and Evolution the Universe	Smithsonian Astrophysical Observatory
Astronomical Search for Origins and Planetary Systems	Space Telescope Science Institute
Solar System Exploration	Jet Propulsion Laboratory
The Sun-Earth Connection	Goddard Space Flight Center

In many ways, both the Space Telescope Science Institute and the Jet Propulsion Laboratory are already functioning, at least in part, as "Education Forums" and designating them as such will further define and formalize their ongoing activities. Other institutions (including Goddard and SAO) should be approached concerning their interest in becoming an "Education Forum." *The pros and cons of carrying out an open competition for the selection of these institutions should be carefully explored.*

The "Education Forums" are only one element of a much larger system. As discussed elsewhere in this Report, a set of regional brokers/facilitators will also be created and extensive use will be made of existing institutions to archive and distribute materials. The overall approach is intended to provide broad geographical coverage, involve many types of institutions in OSS education and outreach, and give investigators multiple paths for establishing collaborations, carrying out educational programs, and distributing the results of their activities.

E. Recognize and Reward Contributions to Education and Outreach

FINDING: Steps must be taken to recognize and reward contributions by members of the space science community to education and the public understanding of science.

If NASA and OSS efforts to engage the scientific community in education and outreach are to be taken seriously, involvement in these activities must be given appropriate recognition both inside and outside of NASA. There are some actions that NASA itself can take. Others can only emerge from the space science community itself with NASA encouragement.

NASA/OSS can:

- Build education and outreach into job descriptions at NASA Headquarters and the NASA Field Centers, allow a modest amount of official time to be used for such activities, include it as an explicit criterion in performance evaluations, and use it as a part of the basis for promotion and award decisions. Education and outreach should be considered activities of comparable importance to attending scientific meetings or giving scientific lectures to colleagues.

- Use awards and other forms of recognition to publicly recognize significant contributions to education and outreach by individuals both inside and outside of NASA. By awarding such prizes at public ceremonies (possibly in conjunction with meetings of appropriate professional societies), OSS would be sending an important message to space scientists and their home institutions—NASA values contributions to education and outreach by the people it supports.

- Ensure that proper credit is given for contributions to an educational activity or product so that the contribution can be recognized both within NASA and by an individuals' home institution. The common practice at some NASA Centers of putting only the Center's name on all products without attribution is unfair. It discourages involvement in education and outreach by not allowing people to get credit for what they have done, thereby placing them at a disadvantage within their own institutions.

OSS must work closely with the space science community to ensure that contributions to outreach and education are also recognized outside of NASA. NASA cannot influence tenure decisions or the many other types of decisions that are the province of the universities or other research organizations. But NASA can work with the community to ensure that it places the same value on contributing to precollege and public education that NASA does.

F. Integrate Science and Education at the NASA Centers

FINDING: The NASA Centers must strengthen the ties between their Education and Science Offices. Center Education Offices must be a resource available to support both individual scientists and Center-managed flight missions. Similarly, Center scientists and Center scientific programs must be strongly coupled to Center-sponsored education and outreach programs.

Education Offices could provide Project Educators for individual flight missions to support both the planning and implementation of education and outreach programs. Such support is now provided by public affairs officers in the development and implementation of public affairs plans. Centers should give at least the same status and priority to education and outreach. Education Offices at the Centers could take on the role of Broker/Facilitator for the scientists at their Center. Education and Science Offices working together can help integrate the results from scientifically related missions (both current and historical) into educationally appropriate products. Incorporation of the results from several missions can achieve a breadth and coherence not possible when each mission is considered in isolation.

The Task Force supports the changes now underway at some Centers to more closely couple science and education. The "Education Forum" approach described earlier should serve to encourage an even closer integration.

VI

Support Local, State, and National Efforts Directed Towards Systemic Reform of Science, Mathematics, and Technology Education

RECOMMENDATION: Educational activities carried out by the Office of Space Science, its projects and programs, and OSS-sponsored scientists should be aligned with and support the inquiry-based systemic reform of mathematics, science and technology education which is now underway throughout the country.

In response to the ever-more complex demands being made upon the problem-solving, information-analyzing, and decision-making capabilities of its citizens, local and state governments across the country have initiated a fundamental upgrading of their educational systems. It is an effort that has received solid support from both political parties since the early 1980s. It is an effort that has given special attention to mathematics, science, and technology education. Plans and programs generated as part of this response are characterized by a focus on the system rather than some of its parts, and by the development of new roles and responsibilities for participants from education, business and industry, community leadership, and government at the local, state, and national level. The scale and scope of the effort directed towards reform is illustrated by the recent publication by the National Research Council of the National Science Standards (see Section VII).

The National Science Foundation (NSF) (through its Education and Human Resources Directorate) is providing major financial support for large-scale experiments in the systemic reform of mathematics, science, and technology education. NSF defines "systemic reform" as a process of educational reform based on the premise that achieving excellence and equity requires alignment of critical activities and components. It is as much a change in infrastructure as in outcomes. Central elements include :

- High standards for learning expected from all students;
- Alignment among all parts of the system— policies, practices, and accountability mechanisms;
- Greater involvement of the public and the community;
- A closer link between formal and informal learning experiences;
- Enhanced attention to professional development;
- Increased coordination between pre-college and postsecondary education institutions.

NSF-funded initiatives in education reform are now underway in states (State Systemic Initiatives), multi-state rural regions (Rural Systemic Initiatives), and large cities (Urban Systemic Initiatives). Regardless of setting, funding by the Foundation requires significant collaboration among the education, public policy, corporate, and public leadership groups touched by these initiatives.

The space science community must understand, support, and become a part of these efforts. They are central to achieving significant improvements in science, mathematics, and technology education in America. They should form the basis for the development of all educational activities and products.

VII
Base OSS-Developed Educational Products and Activities on the Criteria Contained in the National Mathematics, Science, and Technology Education Standards

RECOMMENDATION: Activities and products developed through the OSS-sponsored education and outreach program should be based on the National Science Education Standards as well as national mathematics and technology education standards. These standards provide a foundation for the major developments in the reform of science, mathematics, and technology education now taking place in America.

In particular, the National Science Education Standards, recently developed by the National Research Council in conjunction with science educators and scientists across the country, identifies the critical elements for attaining scientific literacy for all students. These critical elements include:

- The content that students should know (e.g., Objects in the Sky, Earth in the Solar System, Origin and Evolution of the Universe, History and Nature of Science);

- The unifying concepts underlying the content that students should know (e.g., Order and Organization, Evolution and Equilibrium);

- The importance of having all learning — whether for students in the classroom or for teachers in staff development experiences — based on an inquiry approach. Inquiry is defined in the National Science Education Standards as,

  – ". . . a step beyond 'science as a process,' in which students learn skills, such as observing, inferring, and experimenting. The new vision includes the 'processes of science' and requires that students combine these processes and scientific knowledge . . . in ways associated with the processes of inquiry, including asking questions, planning and conducting an investigation, using appropriate tools and techniques, thinking critically and logically about the relationships between evidence and explanations, and communicating scientific arguments."

Participants in the space science program must become aware of and align their education activities with the approach taken in the National Science Education Standards.

The emphasis in the original OSS Education/Outreach Strategy and in this Implementation Plan on creating partnerships and working with the education community is intended to meld the technical expertise of space science researchers, the unique results and scientific insight obtained from space science missions, and the needs and special skills of the education community. The educator side of the partnership can provide the insight and expertise concerning education reform. However, for scientists to be genuinely effective partners, they must have some insight into current developments in education and the implications of those developments on the characteristics of educationally effective programs and products.

To assist the space science community in meeting these requirements, OSS must provide help (see Section VIII). In particular, space scientists must have help in arranging high-leverage alliances and the opportunity to receive both information and training concerning education reform and the National Science Standards.

VIII
Help Scientists Become Involved in Education/Outreach

RECOMMENDATION: OSS must do more than place a new requirement on the participants in the space science program. OSS must take active steps to help the scientific community become involved in education and public outreach—help in looking for high leverage opportunities, help in arranging partnerships and alliances with educators, help in understanding what is now happening in education and what sorts of materials are appropriate for the classroom, help in removing impediments that get in the way of scientists participating in education and outreach even if an individual wants to do so.

A number of approaches are possible to providing such help.

A. Create a Network of Brokers/Facilitators

RECOMMENDATION: OSS should create a network of regional brokers/facilitators whose primary functions will be to search out high leverage opportunities, arrange alliances between educators and scientists, help scientists turn results from space science missions and programs into educationally appropriate products, and arrange for such products to be distributed nationally.

These brokers/facilitators will expedite, assist, serve as catalysts, and simplify the process of channeling NASA expertise into directions that will benefit the educational process and contribute to the public understanding of science. They will carry out a wide range of functions which include:

- Assisting in formulating education/outreach projects and programs which integrate NASA resources into such activities as workshops, curricula, on-line activities, museum exhibits, and planetarium shows;
- Assisting in identifying potential partners and creating appropriate partnerships within specific geographical regions;
- Organizing training workshops for scientists (see below);
- Assisting educators and educational organizations in interfacing with OSS scientists and in locating materials;
- Orchestrating implementation of product creation, evaluation and use throughout local, state, and regional areas;
- Assisting with placing educational materials into regional and national archives and distribution networks;
- Promoting participation in systemic initiatives;
- Taking on special tasks directed towards achieving particular goals such as establishing alliances between minority institutions and the space science research community, and identifying opportunities for participation by these institutions in the space science program (See Sections IX, XIV, and XV.)

It is the view of the Task Force that the broker/facilitator concept is central to the systems approach being recommended for the implementation of the OSS Education/Outreach Strategy. The job is going to be a difficult and demanding one requiring familiarity with the OSS program and scientific community, familiarity with the needs of the education community, links to the education system at many levels, and an aggressive approach to identifying high leverage opportunities and arranging alliances.

The Task Force explored the functions of and possible organizational implementations of the broker/facilitator concept in depth using the results from a 2-day workshop organized by the South Carolina Space Grant Consortium involving Task Force members, educators, engineers, scientists, and administrators. On the basis of the results from this workshop and extensive subsequent discussion, *the Task force has concluded that a wide variety of approaches (with varying emphases) can be taken to carrying out the broker/facilitator role. There is no such thing as a single or a best approach. There are only effective approaches.*

A wide variety of groups/organizations/institutions could take on the broker/facilitator role. Examples include the NASA Space Grant Consortia; associations of informal education entities (museums, science centers, and planetariums) such as the Association of Science and Technology Centers; Department of Education Eisenhower National Regional Consortia; university consortia such as the Universities Space Research Association (USRA) or the Associated Universities for Research in Astronomy (AURA); educational associations such as the National Science Teachers Association (NSTA); professional societies and associations such as the American Association for the Advancement of Science (AAAS), American Astronomical Society, and the American Geophysical Union (AGU); and the McREL (MidContinent Research) centers, among many other possible candidates.

RECOMMENDATION: OSS should experiment with several different approaches to the implementation of the broker/facilitator concept. Selections should be made competitively with specific attention paid to involving a number of different types of institutions and achieving broad geographical coverage.

B. Provide Opportunities for Appropriate Training

RECOMMENDATION: OSS must provide focused opportunities (through workshops or other appropriate means) for training to allow members of the space science research community to become more useful partners in education and effective contributors to the public understanding of science.

In particular, if OSS-supported scientists are to be able to contribute effectively to the educational experiences of *all individuals*, not just to those individuals interested in science careers, the scientists need to understand:

- The reasoning skills and interest of individuals at various levels so that the scientists can develop materials or present information in the most effective manner;
- The nature of the classroom, planetarium and museum environment in order to develop materials or present information in the most effective manner;
- The major emphases of the National Science Education Standards—especially the focus on inquiry—so that they can develop materials or present information in the most effective manner;
- The variety of approaches that can be used (e.g., classroom presentations, curriculum development consultant, museums special events) to become involved in the education of the public.

Such training should provide scientists with an understanding of current developments in education reform and the background and skills needed to make the most effective contribution to the education of the public. This training should:

- Build on effective programs that already exist, such as the Project ASTRO workshops of the Astronomical Society of the Pacific, and the workshops that have been developed and offered through the American Physical Society, the

Division for Planetary Sciences, and the Space Science Institute;

- Be offered at convenient locations to attract the largest participation by scientists, including at American Astronomical Society and Astronomical Society of the Pacific meetings, and as special presentations at large research sites (e.g., NASA Research Centers, large universities) and at the "Education Forums";

- Especially target graduate students who recognize the need to explore a wider range of career options and have an interest in working in education.

C. Remove Contractual and Other Impediments to Participation

FINDING: NASA's and OSS's policies are to encourage widespread participation and involvement by the research community in education and outreach. But, at the same time, NASA itself has created a number of obstructions to prevent the realization of that goal. Such impediments must be systematically identified and removed.

The single biggest problem identified by the Task Force deals with the nature of contracts with and the accounting systems used by institutions such as the Jet Propulsion Laboratory and the Space Telescope Science Institute. At such institutions, OSS is directly and explicitly charged for all of the time spent on education/outreach. In effect, the accounting system demands the purchase of education "by the pound".

NASA policies encourage scientists to regard participation in education and outreach as part of their jobs. NASA accounting systems say that such employees cannot spend time on education unless there is an education account to charge against. NASA policies encourage grantees to spend some portion of their research time on education. NASA contracts say that NASA research funds can only be used for research. At STScI, for example, Guest Observers who might want to spend some fraction of their time on education and outreach are officially forbidden from doing so—unless they can charge their time against the Institute's education budget which is the only place in the Institute budget that can, according to the terms of the Institute contract, be used to support education and outreach. The same problem is embedded in many other contracts. *In this area, there is a fundamental disconnect between policy and practice. This situation should not be allowed to continue.*

RECOMMENDATION: OSS must work with the Headquarters Office of Procurement, the Procurement offices at the NASA Field Centers, and the NASA Resident Office at JPL to explore ways to remove contractual or other impediments to participation in OSS education and outreach programs.

IX
Provide Meaningful Opportunities for Underserved and Underutilized Groups

Profound changes in the composition of the population of the United States are now taking place. According to projections by the Bureau of the Census:

- By 2030, the total elementary school age population of the United States will be equally divided between non-Hispanic whites and all other racial/ethnic groups combined.

- From 2030 to 2050, American Indians, Asian/Pacific Islanders, Hispanics, and African-Americans will together far outnumber non-Hispanic whites in elementary schools, high schools, and new entrants into college and the workforce.

- By 2050, non-Hispanic whites will decline to 53 percent of the total United States population (all ages).

Meeting the future needs of a society based on science and technology will require the involvement of individuals from groups who, at the current time, are not as effectively utilized as they should be in science and technology. This is an urgent matter of national self-interest, not a matter of "political correctness". The issue is not just one of ensuring the future supply of scientists and engineers. It also involves the need to educate all people about the important role that science and technology plays in their lives.

OSS's education and outreach programs must play a role in addressing these issues. A number of steps should be taken ranging from encouraging individual investigators to contribute to the education and training of underserved groups to requiring a more formal commitment for major OSS projects or significant educational initiatives undertaken at the "Education Forum" level. The Task Force expects all the participants in the space science program to establish an atmosphere and an environment of equality and be aware of the problems related to diversity.

FINDING: The Office of Space Science must be committed to the principle that programs developed for underserved/underutilized groups should lead to true and meaningful participation in NASA's space science program.

RECOMMENDATION: Individual investigators supported by research grants should be encouraged to contribute to the training of, involvement in, and broad understanding of science and technology by underserved and underutilized groups.

In parallel with the discussion of Section V-C, incentives for participation in such activities should also be provided through the NASA Research Announcement process with announcements containing explicit goals and evaluation criteria for this aspect of education/public outreach. Programs proposed in response to Announcements of Opportunity should be handled in a similar fashion.

RECOMMENDATION: For major missions and educational initiatives a more formal, structured approach should be taken. Proposed programs and/or partnerships involving underserved groups or minority institutions should be based on an explicit action plan

which sets forth clear goals and includes the following elements:

- Each program and/or partnership must seek to be inclusive and to reflect the diversity of the population within the region to be served. The term diversity includes women, minorities, the disabled, and the economically disadvantaged. Thus any program or partnership should represent the economic and ethnic diversity of the region that is being served.

- Action plans should be developed with a clear approach for measuring the success of the plan. Annual reports should provide evidence of progress in meeting their objectives. Failure to achieve adequate progress should be considered grounds for terminating the program and/or partnership.

Close coordination with the Office of Equal Opportunity Programs will be essential for taking advantage of resources, expertise, and programs that are already in place. *The outcome of NASA's existing efforts directed at minority institutions should be aimed at developing the capabilities of the students, faculty, and managers at such institutions so that they can compete for space science opportunities and funding on the same basis as everyone else.* Additional steps directed towards achieving this goal are discussed in Sections X-D, XIV and XV.

FINDING: The Task Force notes that reaching underserved/underutilized groups also involves reaching the students at many other kinds of institutions that have had little linkage with space science or the space research community.

In particular, increasing numbers of students are taking college courses at two-year and community colleges. More than 40 percent of the students currently enrolled in college in the United States are enrolled in 2-year and community colleges and the percentage is climbing rapidly. A substantial number of these students are minorities. Faculty at these colleges rarely have the opportunity to pursue research or attend scientific meetings because of their heavy teaching loads and budget constraints, yet they are increasingly responsible for teaching college-level science. *Efforts devoted to improving the teaching of science at these institutions can reach a diverse set of students and have a significant impact on increasing the understanding of science in a broad segment of the population.*

X

Enhance the Breadth and Effectiveness of Partnerships Among Scientists, Educators, Contractors, and Professional Organizations as the Basis for OSS Education and Outreach Activities

FINDING: As emphasized in the original OSS Education/Outreach Strategy, partnerships between the space science and education communities must form the core of effective, worthwhile, and highly leveraged education and outreach programs.

Partnerships are required to: combine the scientific expertise of the OSS research community with the pedagogical knowledge of the education community to produce appropriate and effective educational materials; develop and take advantage of opportunities to reach large audiences; build on existing programs and institutions (both inside and outside the government) so that limited resources can be applied in the most efficient way; involve all of the participants in the space science program and link their activities together in a cohesive fashion; develop sustainable conduits for OSS-sponsored education/outreach materials into the education community.

There are several levels of possible partnerships:

- **High leverage partnerships:** involving participation in national initiatives to coordinate the development, use and dissemination of materials related to space science through curriculum developers and national organizations;

- **Statewide and regional level partnerships:** involving State Mathematics and Science Education Coalitions, informal science center initiatives, and teacher professional development programs including pre-service and in-service teacher education through community colleges and universities. The statewide initiatives and some regional programs are particularly important arenas for partnership with industry. State and regional coordination is of special interest to industry because of its effect on the development of a skilled labor pool. Success in competition depends upon the availability of a educated workforce;

- **Local partnerships**: key partners are teachers, individual schools, or school districts, informal science centers, libraries, community groups, community college personnel, and university departments.

Much of the education/outreach work undertaken by OSS-sponsored researchers has been centered at the local level. Such local activities (many of which are done on a voluntary basis) generate good-will, benefit the students and members of the public who participate, have personal value, and are useful for the development and testing of materials. However such activities reach relatively few students and new materials are rarely distributed beyond a limited area. Consequently, they have limited impact. *In order to significantly affect education and the public understanding of science at the national level, the focus from now on must be on high-leverage activities*.

A. Focus on High Leverage Opportunities

RECOMMENDATION: In order to maximize the effect of limited funds and in-kind resources, OSS-sponsored education and outreach programs should be

channeled towards activities having the potential for state, regional or national impact.

The investment of a given amount of money, time, and energy can result in an activity which either has a small or a large impact. OSS and the space science community must actively seek out and give priority to becoming involved in high leverage opportunities. Many possibilities exist. *The important point is for space scientists to begin to think "high leverage" and then focus their energies in appropriate directions.*

- Holding a workshop for 20 teachers may benefit a few schools. Holding a workshop for 20 master teachers can affect the teaching in a school district. Holding the same workshop at a National Science Teacher's Association meeting can reach hundreds of teachers.

- Activities and curriculum materials developed by institutions/organizations such as the Pacific Science Center, the Lawrence Hall of Science, and the National Science Teachers Association are used by large numbers of teachers across the country and reach millions of students. The same time spent on developing a product that benefits a few schools can be used to contribute to materials that are distributed across the country.

- Science museums and planetariums play an important role in public education and the development of teachers in the United States. They attract very large audiences. Worldwide, there are more than two thousand planetariums (with more than half in the United States) and the collective attendance is at least 20 million people per year. Science museums and planetariums are located in communities of all sizes and types across America. They are major community, regional, and national resources. Collaborating in the development of displays and shows—particularly those intended for broad distribution—offers a high-leverage channel for reaching audiences of all types.

- Educational television and other media can be used both to reach large audiences and to give a human face to science. For example, two recent space science-related segments of the "Passport to Knowledge" series—"Live from the Stratosphere" and "Live from the Hubble Space Telescope"—were broadcast over more than 100 PBS stations. The teachers guides, activities, and video tapes produced in conjunction with the series have been used in thousands of classrooms. These programs also showed science as a human activity, revealing that a wide range of skills are needed, teamwork is important, and people of all types are involved in space science.

- Interactive video and multimedia systems can be used to provide interaction among scientists, teachers, and students and museum personnel participating in education programs. They also provide an opportunity for student collaborations across large geographic areas and connectivity between experts, teachers, and their classrooms for guidance in inquiry-based science activities.

The Task Force recognizes that not everyone can or wants to become involved in large activities of national scope. *The real point is to think beyond the obvious—the local school, the workshop for a few teachers, the program that benefits a handful of children— and look for the high-leverage opportunity.* Collaborations are the key to high leverage. Collaborations can be used to add value to existing programs and to take advantage of all the activities that are now underway and the infrastructure that is already in place.

B. Build on Existing Programs, Institutions, and Infrastructure

RECOMMENDATION: In order to make the most effective use of limited available resources, OSS must become aware of and build upon existing programs, institutions and infrastructure.

Building on existing activities is an important aspect of obtaining high leverage. Steps must be taken by OSS to coordinate activities with the organizations carrying out such activities and to investigate possibilities for collaboration.

A wide variety of publicly and privately funded organizations and institutions are now engaged in programs and projects involving curriculum development, teacher enrichment, materials dissemination, public education, educational broadcasting, and many other activities contributing to education and the public understanding of science. Collectively, these represent an enormous resource. *By using such institutions and programs as a basis, the education and outreach activities undertaken by the OSS-sponsored research community can focus on adding value to what is already going on rather than duplicating it.* A few of the many possible examples follow.

- Institutions/Programs that develop curriculum units or other materials to be used nationally, regionally, or at the state or multi- district level:
  - NSF-supported State, Rural, and Urban Systemic Initiatives,
  - National Science Teachers Association,
  - National Council of Teachers of Mathematics,
  - Lawrence Hall of Science,
  - National Science Resources Center,
  - Classroom of the Future,
  - Challenger Centers,
  - Astronomical Society of the Pacific.

- Institutions that provide information on, archive and coordinate the national distribution of educational materials:
  - National Science Teachers Association,
  - National Council of Teachers of Mathematics,
  - U.S. Department of Education Educational Resources Information Centers,
  - NASA Teacher Resource Centers and Regional Teacher Resource Centers,
  - NASA Aerospace Education Services Program,
  - NASA SPACELINK,
  - Eisenhower National Clearinghouse for Science and Mathematics Education,
  - Eisenhower Regional Centers for Science and Mathematics Education,

- Institutions involved in the training of scientists on current developments in education and effective practices:
  - Astronomical Society of the Pacific,
  - American Physical Society,
  - American Geophysical Union,
  - American Association for the Advancement of Science.

- Institutions that coordinate activities and facilitate the exiting of shows, displays, and materials among science museums, planetariums, and other informal science centers:
  - Association of Science and Technology Centers,
  - International Planetarium Society.

- Institutions that promote the advancement of minorities in education and the participation of minorities in science and engineering:
  - National Association for Equal Opportunity in Higher Education,
  - American Indian Science and Engineering Society,
  - National Society of Black Physicists,
  - Minority Students in Physical and Mathematical Sciences,
  - Hispanic Association of Colleges and Universities,
  - Society for the Advancement of Chicanos and Native Americans in Science,
  - American Indian Higher Education Consortium,
  - Quality Education for Minorities Network.

- State Science and Mathematics Education Coalitions
  - National Alliance of State Science and Mathematics Education Coalitions.

The next three sections describe, in more detail, several particular institutions/organizations/groups that the Task Force has concluded must be a special focus for OSS in coordinating its education/outreach programs with others and developing new opportunities for collaboration.

C. Emphasize Collaborations With Planetariums and Science Museums

FINDING: Planetariums and science museums offer a particularly effective means for OSS to reach a broad audience in an environment where people are especially receptive to experiences related to space science:

- Many of the visitors are mixed-age groups, especially families, that have chosen to use their discretionary time to visit the museum or planetarium.
- Large numbers of teachers, especially at the elementary level, use science museums and planetariums to obtain professional development regarding the teaching of space science.
- Many museums and planetariums have extensive outreach programs that serve rural populations that do not have easy access to space science experiences.

In addition, science museums and planetariums have a tradition of presenting experiences using an inquiry, hands-on approach that is well aligned with the National Science Education Standards. Educators at science museums and planetariums can be particularly important partners in developing curriculum materials that can effectively serve both the school and non-school setting.

RECOMMENDATION: Because of their potential for reaching large audiences distributed throughout the country, their importance in communicating science to the public, and their role in both teacher training and materials development, the OSS education and outreach program should place a special focus on science museums and planetariums.

In order to accomplish this goal, OSS should establish a formal relationship with the Association of Science-Technology Centers and the International Planetarium Society that will allow for the needs and resources of each organization to be communicated, and to seek opportunities for joint projects.

D. Coordinate With Other Ongoing Education and Outreach Efforts:

i) Inside NASA

FINDING: Close coordination between the Office of Space Science and other Offices in NASA responsible for and/or involved in Education and Outreach will be essential for the successful implementation of the OSS Education/Outreach Strategy.

Optimizing use of limited available resources demands that education/outreach activities undertaken in the different parts of NASA complement and supplement rather than duplicate or compete with each other.

Two offices within NASA play special roles in the policy development, planning, implementation, management oversight, coordination and direction of the Agency's overall education and outreach programs. Leadership and Agency-wide coordination of NASA's Education Program is the responsibility of the Education Division of the Office of Human Resources and Education. The Office of Equal Opportunity Programs (through its Minority University Research and Education Division) has the responsibility for leading Agency efforts to fully involve minorities and minority institutions in NASA-sponsored research and education programs.

Critical elements of the infrastructure needed to archive and disseminate educational materials developed by OSS researchers and to facilitate partnerships between researchers and educators have already been put into place by NASA's Education Division. The existing network of NASA Teacher Resource Centers can provide an important channel for disseminating educational materials which have been developed and tested at local levels. The Space Grant Colleges and Universities could be a key element of the network of brokers/facilitators which are central to the implementation of the OSS Education/Outreach Strategy. The Education Division can also play a valuable role as a facilitator for OSS so that OSS can utilize established contacts between the Education Division and Education Professional Organizations and key individuals in the education community.

RECOMMENDATION: In order to enhance coordination between the two organizations, the Education Division must continue to be involved in the implementation of the OSS Strategy. Similarly, OSS also must be involved in the planning of major Education Division programs and initiatives to ensure that such activities take into account OSS needs.

FINDING: Close coordination is required between OSS and the Office of Equal Opportunity Programs (Code E).

In order to obtain maximum leverage, OSS activities intended to enhance the participation of underserved/underutilized groups in OSS missions and research programs (see Section IX) must be able to both draw on and build upon ongoing and planned programs sponsored by Code E. *OSS and Code E activities must be far better aligned to ensure the accomplishment of common objectives than they have been in the past.*

RECOMMENDATION: In order to achieve mutual goals of enhanced involvement by underserved/underutilized individuals and institutions in space science missions and programs, OSS must include Code E in its education/outreach planning and be included in the planning, review, and selection of Code E programs as well.

FINDING: Programs supported and capabilities developed by other parts of NASA are also important elements in the implementation of the OSS Education/Public Outreach Strategy.

The Office of Aeronautics' High Performance Communications and Computing Initiative, for example, has played a major role in developing and demonstrating use of the Internet and other advanced communications technologies for a wide variety of education and outreach purposes. *Such programs must continue to be supported and OSS management must continue to be an advocate for, as well as a beneficiary of, these kinds of activities.*

FINDING: Other science program offices within NASA have the same mandates as OSS to involve their programs and research communities in education and outreach. OSS must work with the other parts of NASA to coordinate activities and collaborate on programs of mutual interest.

Each science office should not feel the need to initiate and develop a completely independent set of education and outreach programs. Each science office has different perspectives and is developing or supporting programs which address different aspects of the broad problem of improving science education and the public understanding of science. Such efforts should build upon and cross-fertilize each other. *Where appropriate, joint sponsorship or support should be considered.*

ii) Within Other Government Agencies

FINDING: Successful implementation of the OSS Education/Outreach Strategy would also benefit from close coordination with activities underway at other Federal Agencies particularly those supported by the National Science Foundation (NSF).

As a response to the same general policy guidance given to NASA, the Science Directorates at NSF are now undertaking efforts to increase involvement by NSF-supported researchers in precollege education and communicating science to the public. *In a number of scientific fields (particularly astronomy), there is a substantial overlap between the communities supported by NASA and NSF. The Task Force finds that both Agencies would gain from more closely orchestrating the education and outreach activities being carried out by their respective communities.*

The two Agencies could reinforce each other in assisting their communities to become more involved in education and outreach. Educational materials and programs developed by scientists supported by each Agency could be made more widely accessible. Researchers supported by the two Agencies at the same or neighboring institutions could be encouraged to collaborate to develop wider-ranging education programs than could be undertaken by individuals or small groups working in isolation. The proposed network of facilitators/brokers—appropriately expanded — could effectively serve both communities.

As noted earlier, NSF's Directorate for Education and Human Resources (EHR) is the principal supporter of large-scale efforts directed towards the systemic reform of the teaching of science and

mathematics in states, cities, and communities throughout the United States. The extensively tested materials developed under EHR support are archived and widely distributed throughout the country. *Participation in such programs may be one particularly important means for space scientists to become involved in activities having an impact at the state, regional, or national level.* EHR is also supporting a number of studies to develop approaches to evaluate and assess the effectiveness of education programs.

FINDING: In order to take advantage of and build upon the large investments in science education, assessment, and evaluation already being made by NSF, OSS and its research community must learn about EHR-sponsored activities being carried out at institutions across the country and actively seek opportunities for appropriate collaboration.

RECOMMENDATION: The Task Force concludes that an evolutionary approach should be taken by OSS to exploring opportunities for inter-agency coordination and collaboration.

Initial focus should be on working with those parts of the science side of NSF—such as the Astronomy Division—where mechanisms for coordination of activities are already well established. Strong links must also be developed between OSS and the Education and Human Resources Directorate. A small number of high-leverage activities should be identified which can serve as pilot projects to understand both the benefits and problems associated with coordination and collaboration between the two agencies. Success with such pilot projects can provide the basis for extending the collaboration both within NSF and, eventually, to other Agencies.

E. Involve the Contractors in OSS's Education/Outreach Programs

RECOMMENDATION: Involvement in education and outreach is not just the responsibility of the scientific participants in OSS missions and research programs. All participants—particularly the contractors who receive a significant fraction of the OSS budget—must also assume this responsibility.

Education/outreach activities undertaken by OSS's contractors (and by business and industry involved in the OSS program in general) should be guided by the Implementation Principles contained in this Report.

Like so many others, business and industry have historically participated in education as a community service activity to support the neighborhoods in which they reside. This support is usually at the building level and rarely above the district level.

Corporations are now in the process of rethinking their approach. They are beginning to understand the need for fundamental, system-wide reform; to think about managing education as a "system"; and to act systematically as well as locally in education outreach efforts to avoid reinforcing the status quo and thereby preventing real change. *Companies now know that effective support of systemic and sustainable education reform comes from collaborative efforts at the state level.* As partners in systemic educational improvement, they have been working with other corporations, education officials, and other community leaders to identify the need for reform or improvement in the educational system, and then working over the long term to make those major changes happen in the system.

In this new role, the contribution of the business community to education is not only as a funder, but as an advocate, a watchdog, a convener, a facilitator, a planner, a listener, and an evaluator. The power of a strong collaboration with the corporate community to address the interdependency of states' education and economic systems has been proven. The voice of the business community is heard by politicians, government officials, policy makers, other business contacts, parents, and the general public. The advantage business brings as an agent of educational change derives from business' power as providers of economic activity, as consumers of the system's products, as major taxpayers, and as civic/political players. Business also offers continuity and stability to the educational reform process which experiences frequent change in leadership and shifts in political will.

FINDING: The role of business and industry in support of the implementation of OSS's Education/Public Outreach Strategy is to engage in activities that:

- Align with both NASA and OSS's commitment to improve science, technology, and mathematics education and scientific and technological literacy,

- Maximize the corporation's impact on the inquiry-based, systemic reform of science, technology, and mathematics education.

The primary focus of this aspect of the Implementation Plan is to educate OSS's contractor community about, and involve them in high-leverage educational partnerships. Some corporations will continue to support locally coordinated educational initiatives that "touch" a limited number of students and teachers, but all corporations with education interests must be challenged to commit to higher level, higher impact partnerships and to find new ways to leverage their support of education.

Engaging the corporate community at the policy and planning levels through mechanisms such as the State Mathematics and Science Education Coalitions, is essential. Participation of NASA aerospace contractors and non-aerospace industry in state-level reform coalitions will leverage their involvement in the improvement of mathematics, science, and technology education and focus their effort on meaningful activities in support of national, NASA, and OSS education goals. These activities will require both financial support and company commitment by the NASA contractors.

In an ideal world, many of these activities would be funded by the contractors themselves with a redirection of existing funds used for this purpose towards high-leverage rather than localized activities. In such an ideal world, OSS Requests for Proposals (RFP's) would also include a requirement for inclusion of an education/outreach plan (with appropriate criteria added for evaluation of the proposal) so that industry participation in the implementation of the OSS Education Strategy would be built into contracts and work statements. However, such an approach would have limited value if it simply resulted in the addition of another line item to the budget or an increase in the overhead rate to cover work on education/outreach.

RECOMMENDATION: OSS should work with its contractors and the NASA Office of Procurement to explore ways to develop appropriate cost-sharing arrangements so that contributions to education and outreach can be built into contracts and the activities of the contractor work force.

OSS's contractors, business, and industry must be involved. They are an important part of the Space Science program. They must be part of OSS's education/outreach "Ecosystem".

XI

Make Materials Widely Available and Easily Accessible, Using Modern Information and Communication Technologies Where Appropriate

FINDING: Education and outreach materials developed under OSS sponsorship must be widely disseminated and readily accessible to a diverse audience possessing varied levels of scientific and technical knowledge.

Maximum use should be made of modern information and communications technologies but the limitations of such technologies must also be recognized. *Care must be taken to ensure that such materials are available to all students and teachers—not just those at the best or the wealthiest schools.*

High leverage can be obtained by ensuring that quality products are widely distributed after successful local development, testing, and evaluation. *However, even the best education and public outreach materials do little good unless people know they are there, they can be easily accessed by a variety of means, and they are suitable for and can be readily used by the intended audiences.*

RECOMMENDATION: Many avenues already exist both inside and outside of NASA for the distribution of materials. OSS and the space science research community must become aware of and utilize these existing distribution mechanisms.

OSS, the broker/facilitators and the "Education Forums" must work closely with the NASA Education Division both to ensure that optimum use is made of existing NASA distribution channels and to gain access to other distribution networks as well.

NASA itself (through its Education Division) currently provides several means for both physical and electronic distribution of materials. Materials are available from Teacher Resource Centers (TRC's), located at or near NASA field centers, and the Regional Teacher Research Centers (RTRC's) which exist in most states, typically in association with universities or museums. Teachers who cannot visit a TRC or RTRC can obtain materials by mail through NASA's Central Operations of Resources for Educators (CORE). NASA also provides for electronic distribution of materials in several different ways. Video broadcasts and videoconferences are offered on a regularly scheduled basis through NASA TV. NASA SPACELINK provides on-line computer access to educational materials. Another NASA channel for electronic distribution of materials is through the High Performance Computing and Communications Initiative's K–12 Internet program. This effort reaches a small (but growing) fraction of teachers with Internet connections.

The Task Force notes that the Education Division is currently carrying out a comprehensive re-examination of the Teacher Resource Centers. *Because the issues of access and distribution are so central to implementing the OSS Education/Outreach Strategy, OSS should participate in this re-examination.*

As part of this re-examination, consideration should be given to bringing space science-related materials developed using other federal resources (e.g., NSF, Department of Education) into the NASA teacher resource system. Many programs over the past years have developed space science curriculum materials. Much of this material is used by only a relatively small portion of the target teachers. By identifying relevant materials and incorporating them into the NASA system, these materials can reach a wider audience than is now the case.

The revolution in information technology is clearly one of the principal drivers behind any reconsideration of how materials are archived and distributed.

Satellite television, the Internet, and other developments provide powerful new tools for the distribution of materials and for the development of innovative approaches to classroom instruction. Technology allows students to experience a place, tour a site, control a device, or learn to manipulate equipment through simulations, network links, and virtual reality devices without the necessity to travel to a specific location. Technology allows access to unusual or precious resources such as supercomputers, remote telescopes, robots, and data archives. Technology provides new techniques for visualizing, manipulating, discovering, documenting results, and presenting findings. Technology can allow students to proceed at their own pace in well-crafted activities. It can be used to engage at-risk students, students with learning disabilities or with language barriers through the use of visually, aurally, or other stimulating material. *However, the limitations as well as the opportunities provided by technology must be well understood.*

For example, while video or electronic means of access are widely used (many thousands of educators use SPACELINK every year), the number of classrooms with access to satellite TV or the Internet are, in fact, quite small at present. Current initiatives (supported by the federal government, states, and industry) to provide Internet access to schools across the country are only part of the story. *For the new technology to be truly useful, classrooms must be properly equipped, teachers must be trained in how to make effective use of these new technologies, and, perhaps most important, materials available on-line must be suitable for use in the classroom.* OSS must ensure that OSS-sponsored education and outreach materials placed on-line meet this last criterion. The transition to easy on-line access to and use of materials by all schools, teachers, and students will also take some time. During this period of transition, care will have to be taken to ensure that space science education/outreach materials are available through a variety of means.

Information on the availability of materials must be provided and the availability of this information must be highly publicized. A critical first step will be to create on-line indices of teacher and other outreach resources, and to ensure that appropriate materials are actually available on-line. A theme-oriented approach should be adopted for the creation of indices of materials. "Education Forums "could assume a lead responsibility for organizing, developing, and overseeing these indices but it also should be noted that existing institutions such as the Eisenhower National Clearinghouse already provide an on-line index for science education materials. Whatever approach is taken, *all OSS-sponsored education and outreach materials should be submitted for inclusion in an appropriate index and archive.*

Having the means to easily disseminate materials provides both an opportunity and a challenge. The opportunity is the ability to make education/outreach information and products available for broad use. The challenge is to make sure that such material is scientifically accurate, appropriate for its intended audience, and effective. Quality control in the "Information Age" is a subject requiring particular attention.

XII
Evaluate for Quality, Impact, and Effectiveness

FINDING: OSS-sponsored education and outreach activities, programs, and products must be evaluated for quality, impact, and effectiveness. Formal mechanisms for measurement and evaluation must be put into place to:

- Supply information on activity, provide a top-level description of what's going on, how many scientists are involved, how many teachers, students, or members of the public are reached, how many individuals have accessed or used OSS-developed materials and products, and other meaningful measures needed to adequately characterize the full scope and range of the OSS education and outreach program;

- Ensure the quality of OSS-sponsored educational programs and products making sure that they are aligned with national education standards, have been adequately tested during development, are suitable for deposition in and dissemination by national distribution networks, and are evaluated for effectiveness;

- Provide the oversight necessary to understand the effectiveness and impact of OSS-sponsored major education initiatives and the guidance required to maintain balance, set program priorities, allocate resources, undertake new directions, and ensure the effectiveness of the total OSS education and outreach program.

At the top level, OSS and NASA management must be able to collect fundamental information on activity. Such information is needed for a variety of purposes ranging from meeting the requirements of the Government Performance and Results Act to being able to provide to members of Congress and others a basic inventory (including a description of highlights) of the contents of the OSS Education/Outreach Program.

A reporting system is required to provide this type of basic information. Such a system should be as simple as possible. The Education Division Computer Aided Tracking System (EDCATS) now being developed and tested could provide the basis for the collection of information on OSS-sponsored education and outreach programs. However, the Task Force is concerned about the apparent complexity of the EDCATS system. Use of such an approach may place unreasonable demands for reporting and thereby discourage rather than encourage participation in education and outreach particularly by individual investigators. Care will have to be taken to devise a measurement system that genuinely produces information rather than creating obstacles. The Task Force notes that the proposed highly distributed, decentralized approach to education and outreach does not lend itself well to the centralized collection of information. Nevertheless, *basic information is needed and reasonable means must be developed to obtain it.*

RECOMMENDATION: OSS should work with the Education Division to develop a simple Tracking System for collecting basic information on education and outreach activity.

Development of such a system should draw on existing work to the maximum extent possible. The system should be tailored to focus on the data necessary for NASA and OSS to characterize the overall content of the program and understand, in very broad-brush terms, who is involved, what is being done, and who is being

reached. It should not place unwarranted reporting requirements on participants.

Addressing the next level of evaluation dealing with quality control and assessment of effectiveness and impact is a much more difficult and complex subject. It involves many different types of activities ranging from: a simple review of materials for scientific accuracy; to rigorous testing of curriculum materials in the classroom prior to broad distribution; to formal retrospective evaluation of an education program by a professional outside evaluator. At one end of the spectrum, self-evaluation and the use of simple evaluation instruments such as questionnaires may be sufficient. At the other end of the spectrum, the use of a formal evaluation system can involve the expenditure of substantial time and significant resources.

The OSS education/outreach program will involve a wide range of activities undertaken by a wide variety of individuals and institutions and having a wide range of scope. *Different levels of evaluation are appropriate for different types of education/outreach programs.*

For the smaller programs, a minimum level of resources should be devoted to the evaluation process. Proposals should be required to contain an evaluation plan. The focus of such a plan would usually be on self-assessment.

For the larger programs or programs involving the development of materials intended for wide-spread distribution, a more rigorous approach must be applied. The larger the education project, the higher the percentage of resources that should be devoted to assessment. This is primarily due to the potential national use of products which will be developed and their long life expectancy. Experience has shown that ten percent of the total resources of a major education project is not an unreasonable amount to devote to evaluation both during product development and then retrospectively.

A rigorous approach to evaluation should certainly be taken for major missions and activities undertaken at the "Education Forum" level. In particular, the overall performance of the "Education Forums" will need to be evaluated on a regular basis, preferably by an outside evaluator. If an "Education Forum" is not performing effectively, funding should be terminated and OSS should examine alternative institutional arrangements. Such comprehensive evaluations of "Education Forum" performance should be carried out at 3- to 5-year intervals.

FINDING: The Task Force has concluded that evaluation must be an important element of the implementation of the OSS Education/Outreach Strategy and of future OSS education and outreach activities.

While the discussion above provides some very general guidance concerning approaches to evaluation, the Task Force is not satisfied that it has had the time to adequately address these issues. Therefore, a follow-on activity is recommended.

RECOMMENDATION: OSS should undertake a comprehensive study to develop an integrated approach to the evaluation of the total OSS Education/Outreach program. This study should draw heavily on work being done elsewhere either supported by the NASA Education Division or by the National Science Foundation. The OSS Education/Outreach Council (described in Section XIV) would be an appropriate group for carrying out this study.

At the third level of evaluation, OSS must be able to examine the progress being made in the implementation of its entire education and outreach program. The effectiveness of the total system as well as of the individual pieces must be considered. For this purpose a broad perspective will be required.

RECOMMENDATION: External expertise is required to provide overall guidance, oversight, and evaluation of the relevance and value of OSS education and outreach programs and policies. Such guidance and oversight should be provided either by a Management and Operation Working Group for Education and Outreach or by the creation of a Subcommittee of the Space Science Advisory Committee.

Membership should be broadly drawn from the space science and education communities and others with experience in education and the public understanding of science. The group should include representatives from underserved/minority institutions. It is anticipated that such a group would meet several times a year to review progress and problems in the implementation of the OSS Education/Outreach Strategy and recommend any needed changes. Membership should be set up on a rotating basis.

XIII
Funding

RECOMMENDATION: *As a long-term goal,* OSS should plan to spend 1 to 2 percent of its total budget on education and the public understanding of science.

Based on actual figures for FY 1996 and the OSS proposed budget for FY 1997, this goal translates into a proposed long-term investment of a few 10's of millions of dollars per year as OSS's total contribution to meeting larger national goals.

Such funding would be used to foster a wide variety of activities and put key elements of the "Ecosystem" into place. In particular, support would be provided for:

- The education/outreach components of individual research projects selected through the NRA process;
- An OSS-wide program of small education grants;
- A small number of carefully selected major education programs and projects chosen on the basis of their prospects for having significant regional or national impact;
- A small (four to six in total) set of regional brokers/facilitators;
- The education/outreach components of individual flight missions; and
- The four theme-oriented "Education Forums."

It is critical that a reasonable balance be maintained among all the elements of the OSS Education/Outreach program. No single activity or single element should dominate. *In particular, the Task Force expects that the predominant fraction of the available funding would be used to support individual or mission-oriented education/outreach programs and projects carried out across the country with the direct involvement of the OSS research community.* As discussed in Sections XII and XIV, decisions regarding continuing long-term support of groups of groups and institutions (in particular, the "Education Forums" and the broker/facilitators) should be based on periodic evaluations of performance.

The Task Force recognizes that some time (and several budget cycles) will be required to achieve this goal, to phase in a set of activities that could effectively use this funding, and to work out all the details of the funding arrangements. Many of the missions now under development, for example, were planned and budgeted without making provision for a significant education/outreach program. For these missions, it is unrealistic to expect that significant funds could now be reprogrammed for this purpose. This goal should be built into the planning and budgeting for future missions and research programs.

XIV
Next Steps

The Task Force has identified a specific subset of the total of more than 50 individual Findings and Recommendations presented throughout this Report which require near-term actions on the part of OSS management in order to actually proceed with the development of the "Ecosystem" for space science education and public outreach.

- OSS must make a commitment to provide adequate funds for education and outreach, identify the source of funds, and allocate those funds appropriately. (See Sections V and XIII.)

- As indicated in Sections V-C and IX, education, outreach, and the provision of opportunities for underserved/underutilized groups must begin to appear as specific goals (with appropriate evaluation criteria) in all OSS AO's and NRA's. These aspects of proposals should be reviewed with the same professional care and expertise as is now done for the scientific aspects of proposals.

- OSS should begin discussions with candidate organizations regarding their assuming the role of "Education Forums" and to more precisely define the scale and scope of the activities to be undertaken by these centers for space science education. While it appears that there are reasonable choices for institutions to assume the role of "Education Forum" for the four OSS scientific themes, the pros and cons of carrying out an open competition for the selection of these institutions should be carefully explored. (See Section V-D.)

- OSS should initiate action to select and fund the first set of brokers/facilitators. Initial selections should be made competitively for a 2- to 3-year period with careful attention paid to assessment of performance throughout that period. Several types of groups/institutions should be selected to allow a thorough exploration of a variety of approaches to carrying out this function. In order to meet the goals described in Section IX, at least one of the broker/facilitators selected should involve a minority institution or (preferably) a consortium of minority institutions/organizations specifically charged with establishing alliances between minority institutions and the space science research community and identifying opportunities for those minority institutions to participate in the space science program. (See Sections II, VIII, and XV.)

- OSS should initiate discussions with a variety of institutions and organizations outside of NASA to explore the role such groups might play in the implementation of the OSS Education/Outreach Strategy. Examples of such groups include (but are not limited to) the National Science Foundation, the Association of Science and Technology Centers, the International Planetarium Association, the National Science Teachers Association, professional organizations such as the American Astronomical Society and the American Geophysical Union, and OSS's contractors. (See Sections XI-B,-C,-D, and -E.)

- An OSS Education/Outreach Management Operations Working Group (or perhaps an

Advisory Subcommittee to SScAC itself) should be set up to oversee progress with the implementation of the Education/Outreach Strategy, review accomplishments, and recommend changes in the implementation plan which may be required on the basis of performance and experience. (See Section XII.)

- Based on previous recommendations, it is clear that close coordination of all activities and a strong interaction among the various institutions and organizations participating in the OSS Education/Outreach program must be achieved if the proposed approach is to realize its full potential. To achieve such coordination, the Task Force recommends that an OSS Education/Outreach Council be set up to assure optimized performance across the entire "Ecosystem". Membership of such a group should include representatives from all the key groups playing a role in the execution of this Implementation Plan—OSS, the NASA Education Division, the Office of Equal Opportunity Programs, the "Education Forums", the broker/facilitator groups, and other appropriate participating organizations.

XV
Issues Requiring Further Attention

There are a small number of critical issues that the Task Force concludes require more attention than could devoted to them during the course of this study. Substantial additional work will be required to adequately address these issues.

- The subjects of assessment and evaluation are difficult ones. As discussed in Section XII, some organized, reasonable way must be developed to keep track of what is going on and report the highlights. But beyond the collection of numerical data, there also must be genuine measures of the quality of materials developed and the effectiveness of the operations of the "Ecosystem" as a whole. Formal evaluation of every individual task is clearly not practical. Use of a formal evaluation system (including the use of outside evaluators) is, however, appropriate at the mission or "Education Forum" level. The recommended OSS Education/Outreach Council should undertake, as one of its first activities, a comprehensive study to develop an integrated approach to evaluation of the total OSS Education/Outreach program. The results of this study should be reviewed by the Education/Outreach Management and Operations Working Group or Advisory Subcommittee.

- At the present time, OSS and the space science community do not have an adequate understanding of the skills, capabilities and needs of minority/underserved institutions and their students. Steps (including visits and consultation with appropriate professional organizations) must be taken to achieve such an understanding. Attention must also be paid to finding the most effective mechanisms (whether through the creation of partnerships or other means) to involve such institutions in the space science program and create real opportunities for participation. Beyond the coordination between OSS and the Office of Equal Opportunity Programs discussed in Section X-D(i), a genuine long-term partnership must be forged between the two organizations. Codes E and S must work more closely together than they have in the past to address a difficult and long-term problem.

Finally, there are important issues associated with the need for possible changes in the training and support of graduate and postgraduate students. The National Science Foundation's Directorate for Mathematical and Physical Sciences has recently published a Report recommending a number of possible changes in the nature of graduate programs and in the modes of support for graduate students. The American Astronomical Society has also begun an intensive examination of these issues directed towards the astronomical community. OSS is a significant source of support for graduate students in the physical sciences in the United States—all of whom are affected by the same trends and forces which have triggered these studies. SScAC should consider undertaking a re-examination of OSS's basic policies towards the support of graduate students. This re-examination should consider such issues as the nature of future professional opportunities and whether OSS should consider supporting students interested in science education. It should build upon existing and ongoing work and focus on the unique circumstances and needs of students in the space science community.

XVI
Concluding Remarks

The Task Force believes that, by forming appropriate partnerships with the education community, by consciously and deliberately seeking the highest leverage opportunities through such partnerships, and by adopting a broad systems approach to the implementation of its education program, OSS and the OSS research community can make a significant and lasting contribution to improving education and raising the public understanding of science.

Many space scientists are already willingly and enthusiastically involved in education and outreach. The systems approach outlined in this Implementation Plan should serve to channel the efforts of the space research community in the most productive directions while still encouraging individual initiative and creativity. It should promote the best use of the time and talents of OSS-supported scientists and the unique results being obtained from OSS research programs and spaceflight missions. It should help foster a wide range of alliances between the research and education communities and, in so doing, contribute to the solution of significant national problems.

The overall approach described in this Report is an experiment. The focus on process as the centerpiece of this experiment, rather than on the identification of a set of specific programs, represents a deliberate choice by the Task Force to depart from the practice of simply creating a collection of stand-alone activities having purely local impact. The proposed process offers the prospect of enormous amplification of OSS's education/outreach efforts. The only way to tell whether the experiment will work is to try it. Flexibility will be required, progress on the experiment will have to be monitored closely, and adjustments made on an ongoing basis.

Realistic expectations are important. No single education or outreach program undertaken or sponsored by OSS will, by itself, have a significant, long-term, sustainable impact on the American educational system. Rather, it will be the total effect of a broad ensemble of high-leverage activities carried out over a long period of time which can make a difference. A long-term commitment is crucial for success. OSS must be prepared to make such a long-term commitment if it is to achieve its Education and Public Outreach goals. The space science community must be prepared to make such a commitment if they are to demonstrate their ability to contribute to larger national goals and, in so doing, enhance the case for continued support of their research.

"Each one has the right to share in the knowledge and understanding which society provides."

A. Einstein 1936

Appendix A
Task Force Charter

Background:

The Office of Space Science (OSS) Education/Public Outreach Strategic Plan "Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs" was released in March 1995. It announced a major new commitment by OSS to make education and public outreach integral components of all OSS flight programs and research disciplines, making education and public outreach a responsibility for managers and NASA-supported scientists at NASA Headquarters, NASA Centers, universities, and research institutes across the country. The NASA Strategic Plan specifically singles out education as one of the fundamental operating principles to be embodied in the conduct of every NASA activity. Producing the finest scientists and engineers for the twenty-first century, and raising the scientific and technological of all Americans are identified as major national goals in the White House report "Science in the National Interest". The OSS Education/Public Outreach Strategy is a direct response to these charges.

Having announced the new policy direction, the next question which arises is how to actually implement it. Effective implementation will require the answers to a wide range of questions dealing with the mechanisms, policies, and practices which must be put into place in order to realize the goals of the strategy.

Charter:

The purpose of the OSS-Space Science Advisory Committee Education/Public Outreach Task Force will be to frame the issues which must be addressed in the implementation of the OSS Education/Public Outreach Strategy; seek out opinions, ideas, and suggestions from the various concerned communities as to how the strategy should be implemented and what policies and practices should be adopted; examine the pros and cons of possible alternative approaches to implementation of the strategy; and develop a set of possible approaches for consideration by the Space Science Advisory Committee and the Associate Administrator for Space Science. The group will be set up as an independent study team, will gather data and carry out fact finding concerning various approaches to implementation of the OSS Education/Public Outreach and report its findings to the Space Science Advisory Committee and the Associate Administrator for Space Science on a regular basis. Final recommendations to OSS concerning the implementation of the strategy will be made by the Space Science Advisory Committee.

Membership:

Members of the Task Force will be drawn from the science and education communities and will broadly represent those constituencies who will both implement and benefit from OSS education and public outreach programs and activities. In order to obtain as wide a variety of ideas and perspectives as possible concerning the implementation of the OSS Education/Public Outreach Strategy, representatives will be selected from the space research community, the formal and informal education communities, practicing teachers

at several levels in the education system, NASA Headquarters, NASA Centers and research institutes, minority universities and colleges, and industry. To assure appropriate linkage between OSS planning and the formal Advisory Committee structure, the Task Force will be co-chaired by individuals from the Space Science Advisory Committee and NASA Headquarters. The list of members is contained in Attachment A.

Duration:

Following approval of the Study Plan and Task Force membership by the Space Science Advisory Committee and the Associate Administrator for Space Science, the Task Force is expected to have its first meeting in September 1995. A maximum of four meetings of the Task Force are expected to be held in the period September 1995 to April 1996. Regular progress reports on Task Force activities and findings will be provided to the Space Science Advisory Committee at that Committee's Fall 1995 and Winter 1996 meetings. Draft reports concerning findings and alternative approaches will be circulated for comment to the Space Science Advisory Committee members and other knowledgeable individuals in the space science and education communities. A Final Report will be submitted to the Space Science Advisory Committee on or before June 1, 1996. Additional details concerning the study approach and plan are contained in Attachment B.

Approved:
WESLEY T. HUNTRESS, JR.
Associate Administrator for Space Science

Approved:
ANEILA I. SARGENT
Chair, Space Science Advisory Committee

Appendix B
Task Force Membership

Reta Beebe (Co-Chair) is Professor of Astronomy at New Mexico State University. Her area of expertise is planetary atmospheres. She was a member of the Voyager team, is currently an Associate Member of the Galileo imaging team, and utilizes the Hubble Space Telescope. Her teaching career spans 37 years, beginning with junior high science teaching and continuing with a strong educational outreach program throughout her career. She is a member of the Space Science Advisory Committee.

Clarissa Bowman is the Coordinator, Science Honors Program Math/Science Department, Navajo Community College, Shiprock New Mexico. Her primary duties are to recruit and encourage Native American students to pursue careers in science, engineering, and technology and to develop science and math enrichment programs for Native Americans. She holds a BS degree in Cell Biology/Chemistry from Northern Oklahoma State University. She is a member of the NASA American Indian Science and Technology Education Consortium and the American Indian Science and Engineering Society.

Carol Christian heads the Office of Public Outreach at the Space Telescope Science Institute. This office brings research results from the Hubble Space Telescope and other NASA astrophysics missions and programs to the public. Dr. Christian is also Project Director for the Science Information Infrastructure (SII) Education Program which provides scientific and technical information to the public and the education community through the establishment of electronic linkages with the nation's science museums. She is a member of the Association for the Advancement of Computing in Science which sponsors numerous meetings regarding use of the Internet for science and technology education.

E. Julius Dasch Education Division, NASA Headquarters manages the NASA National Space Grant and EPSCoR (Experimental Program to Stimulate Competitive Research) programs. His degrees, all in geology, are from Sul Ross State University (BS), University of Texas, Austin (MA), and Yale University (MS, PhD). After a Fulbright Postdoctoral Fellowship at the Australian National University, he taught geology and geochemistry at Oregon State University, Corvallis. His research has primarily been in isotope geochemistry resulting in nearly 150 publications in marine geochemistry, geochronology, and science education. He is editor-in-chief of the two-volume Encyclopedia of Earth Sciences published by Macmillan Reference USA in 1996.

Shelley Fisher has extensive experience in science education. She taught ninth grade science for 23 years with the Sand Springs, Oklahoma Public Schools with a particular focus on aerospace education. During 1995–96, she was the President of the National Science Teachers Association and now serves as the Retiring President. She is currently the Science Education Consultant for the State of Wisconsin and serves on the Advisory Board for the Wisconsin Space Grant Consortium.

Linda French is Associate Professor of Physical Science, Department of Liberal Arts and Sciences,

Wheelock College. She has conducted research on the physical properties of small solar system objects and has been deeply involved in curriculum development and the training of pre-service teachers. Since 1992, she has been Education Officer of the Division for Planetary Sciences of the American Astronomical Society. She also has been associated with the Science Education Department, Harvard-Smithsonian Center for Astrophysics where she was the Project Manager for Project SPICA.

William Hammers, PhD, taught high school mathematics for three years and university mathematics for sixteen years. He left teaching to work in operations analysis for Boeing Military Airplanes and then moved to a senior engineering position at Boeing Commercial Airplanes. Dr. Hammers is now a program manager at Cessna Aircraft Company. He also serves as the Executive Director of the Kansas Mathematics and Science Education Coalition and as President of the National Alliance of State Science and Mathematics Coalitions.

James Houck is the Kenneth A. Wallace Professor of Astronomy, Cornell University. He is a recipient of the Clark Award for Distinguished Teaching at Cornell and the NASA Medal for Exceptional Scientific Achievement. He is a member of the Space Science Advisory Committee.

William Jackson is Professor of Chemistry at the University of California, Davis. He has taught at the University level for over twenty years. He is particularly interested in the education of minority students in science and engineering having served on many national committees and been an advocate before Congress on this issue. His research interests are in the chemistry of comets, reaction dynamics and laser chemistry and he has authored over a hundred papers in these fields.

Paula Keener-Chavis is Director of the South Carolina Statewide Systemic Initiative's Charleston Math & Science Hub. She has an MS in Marine Science from the College of Charleston and has conducted extensive research in marine habitats of the South Atlantic. She has written articles for professional and trade publications and has produced a marine science text for teachers. Keener-Chavis is a member of a number of local, state, and national professional organizations and represents South Carolina on the Board of the National Marine Educators Association.

David Leckrone is the Senior Project Scientist on the Hubble Space Telescope Project at the NASA Goddard Space Flight Center. He is an active researcher on the ultraviolet spectra of hot stars with the HST and other space observatories. He is involved in the public outreach activities of the HST program, and has served as coordinator of education programs within the Space Sciences Directorate at Goddard.

Jorge Lopez is Associate Professor of Physics at the University of Texas at El Paso. He received his PhD in Physics from Texas A&M University in 1986 and held postdoctoral positions at the Niels Bohr Institute (Copenhagen, Denmark, 1985–87) and The Lawrence Berkeley Laboratory (1987–89). He was the 1994 Chair of the Committee on Minorities of the American Physical Society. His current research is in the areas of gravity wave detection and nuclear physics. He is also involved in science education at the elementary, high school and university levels.

Victor Mayer recently retired from The Ohio State University where he was Professor in the Department of Educational Studies, the Department of Geological Sciences and the School of Natural Resources. His work has centered on in-service and pre-service teacher education and science curriculum development. He has also taught in junior and senior high schools in Colorado. He collaborated with colleagues at OSU and the University of Northern Colorado and teachers in Ohio and Colorado to develop a comprehensive approach to Earth Systems Education. He is currently a Visiting Research Scholar at the Center for School Education Research of Hyogo University of Teacher Education (Japan) where he is continuing development of the concept of Global Science Literacy.

Patricia Reiff is Professor and Chairman of the Department of Space Physics and Astronomy at Rice University. She has held research and faculty positions at Rice since 1976. Dr. Reiff has participated in a number of NASA missions in magnetospheric physics and has also been involved in the development of Internet-based displays on Earth and Space Science for use in science museums. She is currently serving on the Public Education Committee of the Space Physics and Aeronomy Division of the American Geophysical Union. She is a member of the Space Science Advisory Committee.

Jeffrey D. Rosendhal (Co-Chair) is the Assistant Associate Administrator for Education and Outreach in NASA's Office of Space Science (OSS). He is responsible for all OSS activities dealing with education and the public understanding of science. Following service as a faculty member in the Astronomy Departments of the University of Washington, the University of Wisconsin, and the University of Arizona, he joined NASA Headquarters in 1974 where he has held a variety of research and program management, planning, and policy positions. Recognition of his work has included receipt of the NASA Outstanding Leadership Medal, the Presidential Rank Award of Meritorious Executive, and election as a Member of the International Academy of Astronautics.

Dennis Schatz is Associate Director for Education at the Pacific Science Center in Seattle where he directs all the Center's education programs. He is also Principal Investigator for an NSF Local Systemic Change Initiative. A research solar astronomer prior to his career in science education, he has been with the Pacific Science Center for 20 years and was previously with the Lawrence Hall of Science. He has written five science activity books for children. Dr. Schatz received the 1996 Distinguished Informal Science Educator Award from the National Science Teachers Association.

Frederick Shair has been Manager of the Educational Affairs Office at JPL since 1993. From 1989–1993 he served as Dean of Natural Sciences and Mathematics at the California State University, Long Beach. From 1965–1990, he was a Professor of Chemical Engineering in the Division of Chemistry and Chemical Engineering at Caltech. He helped develop the Summer Undergraduate Research Fellowship (SURF) program which involves around 250 students each summer and is now in its 18th year. Dr. Shair has served on a number of public and professional committees including service in 1990-1991 as President of the national organization of Sigma Xi.

Phyllis Sledge teaches at the Aldrin Elementary School in Fairfax County Virginia. She holds a BS degree in Education from Morgan State University and an MEd degree in Education Leadership from George Mason University. She has extensive classroom experience at both the elementary and middle school levels and in the review and development of curriculum materials for the Fairfax County and Chicago Public School Systems. She has served as an education consultant for numerous organizations including the National Geographic Society and the National Air and Space Museum. In 1995, she flew on the Kuiper Airborne Observatory as a member of the final class of FOSTER Teachers.

APPENDIX C
Schedule of Task Force Activities

- Study Planning —June–August 1995
- Organizational meeting—September 20–21, 1995 (Washington)
  - Development of issues
  - Subgroup assignments on individual topics
- Status report to SScAC—November 14, 1995
- Task Force Meeting—November 28–29, 1995 (Annapolis)
  - Review of subgroup reports
  - Development of questionnaire
- Release of Survey and Questionnaire—December 15, 1996
- Task Force Meeting—February 13–14, 1996 (Washington)
  - Review of questionnaire responses, preliminary findings, report outline, writing assignments
- Status Report to SScAC—March 4 1996
- Charleston Workshop—March 26–27, 1996
  - Spacegrant Colleges and Universities as Brokers/Facilitators
- Task Force Meeting—April 22, 23, and 24, 1996 (Las Cruces)
  - Detailed review of findings and recommendations, process for study completion, writing assignments
- Preparation of Mark I report—May/June 1996
- Presentation of findings to SScAC—June 18, 1996
- SScAC review of Mark I report—June/July 1996
- Preparation of Mark II report and additional review by SScAC—July/August 1996
- SScAC Review/Discussion of Mark II report—October 1, 1996
- Preparation of Mark III report/Publication—October 15, 1996 following final review and approval by SScAC

Appendix D
General References

American Association for the Advancement of Science. *1990*. Project 2061: Science for All Americans.

American Association for the Advancement of Science. *1994*. Project 2061: Benchmarks for Science Literacy.

Astronomical Society of the Pacific. *1996*. Project ASTRO: How-To Manual for Teachers and Astronomers.

Charleston Math & Science Hub and the South Carolina Space Grant Consortium. *1996*. A Look at Regional NASA Space Grant Facilities: Keys to Implementing the Office of Space Science's Education/Public Outreach Strategy.

National Aeronautics and Space Administration. *1992*. NASA's Strategic Plan for Education: A Strategy for Change, 1993–1998.

National Aeronautics and Space Administration. *1994*. Equal Opportunity and Diversity Management Plan.

National Aeronautics and Space Administration. *1995*. Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs.

National Aeronautics and Space Administration. *1995*. NASA Science Communications Strategy: Final Report of the NASA Science Communications Working Group.

National Aeronautics and Space Administration. *1995*. Space Science for the 21st Century: The Space Science Enterprise Strategic Plan.

National Aeronautics and Space Administration. *1996*. Strategic Plan.

National Aeronautics and Space Administration. *1996*. Science in Air and Space: NASA's Science Policy Guide.

National Council of Teachers of Mathematics. *1989*. Curriculum and Evaluation Standards for School Mathematics.

National Council of Teachers of Mathematics. *1991*. Professional Standards for Teaching Mathematics.

National Research Council. *1994*. NASA's Education Programs: Defining Goals, Assessing Outcomes.

National Research Council. *1994*. Cultural Diversity and Early Education: Report of a Workshop.

National Research Council. *1995*. Reshaping the Graduate Education of Scientists and Engineers.

National Research Council. *1995*. Reinventing Schools: The Technology is Now.

National Research Council. *1996*. National Science Education Standards.

National Science Foundation. *1993*. The Federal Investment in Science, Mathematics, Engineering, and Technology Education: Where Now? What Next?

National Science Foundation. *1995*. Graduate Education and Postdoctoral Training in the Mathematical and Physical Sciences: A Workshop Report.

National Science and Technology Council. *1994*. Science in the National Interest.

National Science and Technology Council, Committee on Education and Training. *1995*. A Strategic Planning Document for Meeting the 21st Century.

Percy, John R., editor. *1996*. Astronomy Education: Current Developments, Future Coordination. San Francisco, California: Astronomical Society of the Pacific.

Stith, James H. *1996*, Making a Difference: Ethnic Diversity in Physics. Physics Today. Volume 46 Number 7, pg. 39.

Sussman, Art, editor. *1993*. Science Education Partnerships: Manual for Scientists and K–12 Teachers. San Francisco, California: University of California.